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LEONARD W. WING

Agricultural and Mechanical College of Texas

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EDITORIAL PAGE

The study of cyclic fluctuations appears to have grown enough to indicate need for a depository where papers on various phases will be available to those interested. In addition, the Journal of Cycle Research will serve as a place where workers in the field will be able to publish the results of their studies.

No editorial liberties will be taken with any paper, and no attempt will be made to establish a "style" (whatever "style" means). The craftmanship of all papers is that of their authors.

The Foundation for the Study of Cycles hopes that this journal will stimulate study on cycles and aid in shedding light upon many baffling problems.

AN ECONOMIC CYCLE

THE 17 2/3-YEAR RHYTHM IN LIABILITIES OF COMMERCIAL AND INDUSTRIAL FAILURES IN THE U. S. 1857-1950

By Edward R. Dewey*
Foundation for the Study of Cycles
New York, New York

SUMMARY

1. Liabilities of commercial and industrial failures in the United States from 1857 to 1950 inclusive show evidence of a rhythmic fluctuation with a period very close to 17 2/3 years.

2. The average amplitude of the waves is 51% above and 34% below the trend used in the study.

3. The ideal time of crest is the mid point of 1893 and 17 2/3 years plus and minus from that time. The wave is symmetrical and the ideal time for lows is 1866½ (i.e. end of 1866) and every 17 2/3 years thereafter.

4. The last low of this 17 2/3-year wave, ideally due at 1937 1/6 (i.e. end of August, 1937) was delayed about eight years by World War II. This raises the question as to whether or not the current crest, due mid-1946, may not be delayed similarly, even though the wave may be expected eventually to revert to the old pattern, if it is real.

5. Analysis of the figures shows evidence of other rhythms which must be isolated and evaluated before any except the most general projections should be made.

6. No attempt is made to explain the cause of this behavior, or to determine its statistical significance, but the comment is made that other phenomena show waves of the same length with turning points coming at the same time which repeat themselves over much longer periods of time.

THE DATA

Figures for the liabilities of commercial and industrial failures in the United States are available annually for 1857 to 1874 inclusive; quarterly from 1875 to 1893 inclusive; and monthly from January, 1894 to date. However, in this study, only annual data were used.[1,2,3]

There are two relatively unimportant discontinuities in the figures. From 1933 forward, real estate and financial figures were omitted from the series.[2] This action reduced liabilities by about 10% for 1933, the only year for which figures are available on both bases.

In 1939 a change was made in the opposite direction by including voluntary discontinuances.[2] This action increased liabilities for that year by about 8½% (as we know because both figures are available for that year also).

To compensate for these two alterations, the figures for 1934 to 1938 inclusive were multiplied by 1.09205 before the beginning of the analysis.

It should be noted that data for 1945, 1946, 1947, 1948, and 1949 have been corrected to exclude the figures of liabilities of railroad failures, in order to correspond to the figures prior to 1945.[3] Because of this fact the figures used will not agree with some of the figures of liabilities that have been published during the past few years.

The data are given in Table 1 and are charted in Figure 1.

ANALYSIS

Preliminary analysis of the figures shows the presence of an important rhythm about 9 years in length, shows an average 6-year wave, and gives a hint of a rhythm of about 4½ years.

In addition, a wave of about 54 years is also seemingly present, but of course in so short a period of time this wave has not had an opportunity to repeat.

The data were converted to logarithms and, to eliminate the distorting effect of the three shorter rhythms (4½-, 6-, and 9-year, respectively), were smoothed by a 9-year moving average.

The effect of the 9-year moving average is to eliminate completely any 9- and 4½-year waves that may be present, to eliminate 116.7% of any 6-year saw-tooth waves that may be in the series, and of course to minimize by one half any 18-year waves that are present and are of the usual saw-tooth shape.[4]

A chart of the 9-year moving averages is shown by the solid line in Figure 2. The presence of four consecutive waves of about 18 years in length is clearly evident. The crests are 18, 18, and 17 years apart, respectively. The lows are much more irregular, being 17, 19, 13, and 28 years apart.

The 18-year wave can be seen more easily and evaluated more accurately if the smoothed figures are expressed as percentages of trend. The proper trend to use for the purpose is an 18-year moving average, centered, because such a moving average will effect a complete elimination of the 18-year wave,[4] and therefore permit it to reappear in proper amplitude in the percentages of trend.

It is also necessary to eliminate as nearly as may be the distortions caused by the Civil War and by World War II. (The distortions caused by World War I were not great enough to necessitate removal.) Elimination of war distortion was effected by a straight line (log) interpolation between 1860 and 1866 and between 1939 and 1947.

The interpolated values for the war years are as follows:

*With the assistance of Mary Louise Didriksen

Civil War

Year	Liabilities (000 omitted)	Log
1861	75	1.874
1862	70	1.846
1863	66	1.818
1864	62	1.789
1865	58	17.60

World War II

Year	Liabilities (000 omitted)	Log
1940	185	2.268
1941	178	2.274
1942	191	2.281
1943	194	2.287
1944	197	2.293
1945	200	2.300
1946	202	2.306

Of course, these interpolations do not give the actual liabilities of failures which would have taken place if there had been no war, but they are much closer to such values than the distorted behavior that actually took place.

Using these values, the 9-year moving average in Figure 2 assumes the shape shown by the dot and dash line marked " A ".

The 18-year moving average, centered, is also shown in Figure 2 by means of a dashed line. The 18-year moving average, using adjusted values, is shown by a dotted line marked A prime.

The differences between the 9-year moving average and the 18-year moving average, in both cases using the adjusted figures, are shown in Figure 3. The length of the rhythm appears most reasonably to be 17 2/3 years and a perfectly regular 17 2/3-year wave, based on 1893 for crest, is superimposed by means of a broken line.

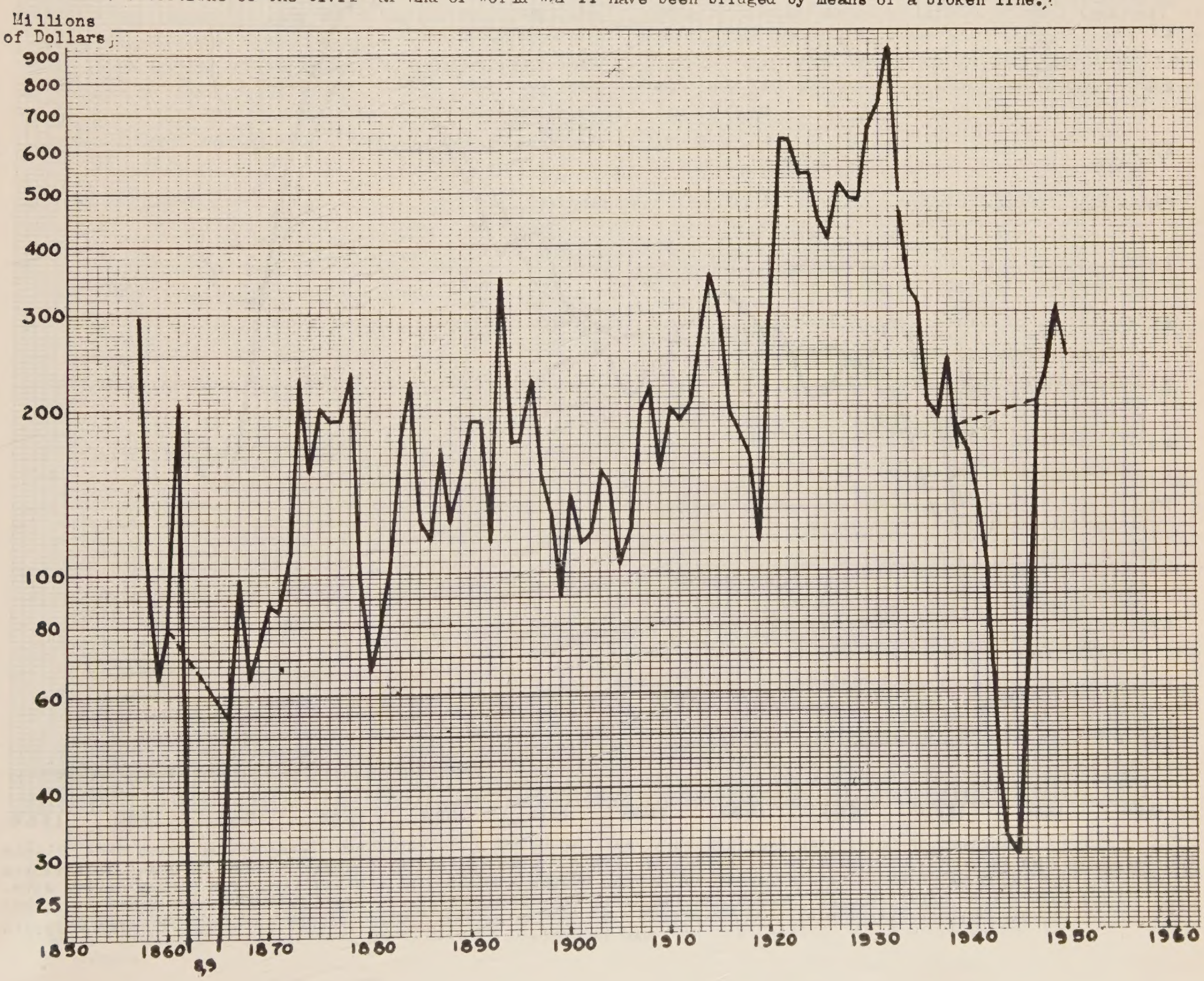
The differences between the two curves are also thrown into a periodic table of 17 2/3 years in length in order to determine as nearly as possible the amplitude and probable shape of the wave on the assumption that its length is really 17 2/3 years.[5]

However, the effect of a 9-year moving average upon a 17 2/3-year saw-tooth wave is to remove 50.94% of the wave.[4] We must therefore adjust the wave disclosed to get the amplitude of the 17 2/3-year wave in the original logs. Assuming that the wave is of the usual saw-tooth shape, the multiplying factor is 2.038.[4] This calcu-

Fig. 1

The Liabilities of Commercial and Industrial Failures in the U.S. 1857-1950

(Distortions of the Civil War and of World War II have been bridged by means of a broken line.)



lation gives us logs of $\bar{2}.179$ and 1.821 or positive and negative values of 151% and 66% of trend, respectively.

The wave proves to be symmetrical with ideal highs in 1893 and 17 2/3 years plus and minus from this point and with lows 8.83 years later. This would put one of the lows of the ideal wave at exactly 1866½ (i.e. end of 1866).

PROJECTIONS

The current crest of the 17 2/3-year wave was ideally due in mid-1946.

However, as the last trough, which was ideally due in 1937 1/6 (i.e. end of August, 1937), came eight years late in the actual figures and six years late in the 9-year moving average, it would seem extremely doubtful if the current crest of the 17 2/3-year wave could possibly come on time.

Of course we cannot know definitely until some years hence, but one would be very foolish to expect so major a distortion to be corrected so suddenly.

If the rhythm continues and reverts to the pattern of 1857-1928, ideal crests and troughs of the 9-year moving average can be projected as follows:

Crests	Troughs
	1954 5/6
1963 2/3	1972 1/2
1981 1/3	1990 1/6
1999	2007 5/6
etc.	etc.

SIGNIFICANCE

No attempt will be made in this paper to suggest a cause for the observed rhythm, or to evaluate its statistical significance.

Nevertheless some comment in regard to the observed behavior may not be out of place.

First of all, looking at the figures objectively, we see merely five waves, the first and last badly distorted and perhaps even created by the Civil War and World War II.

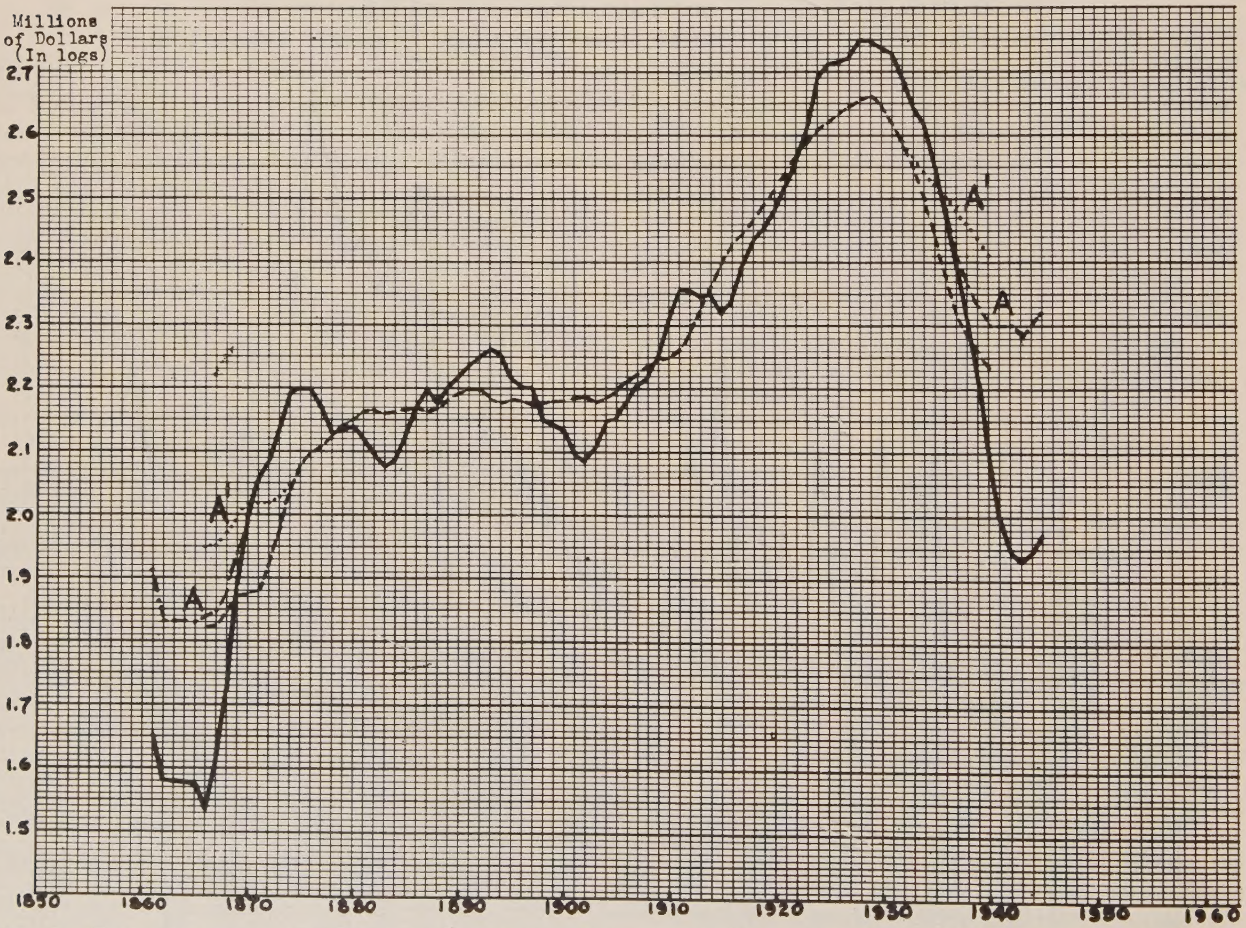
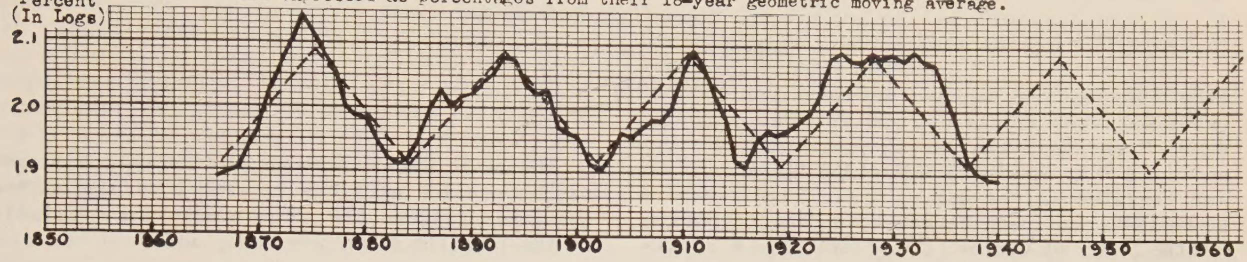


FIG. 2. THE LIABILITIES OF COMMERCIAL AND INDUSTRIAL FAILURE IN THE U.S. 1857-1950, SMOOTHED BY MEANS OF A 9-YEAR GEOMETRIC MOVING AVERAGE. TOGETHER WITH AN 18-YEAR GEOMETRIC MOVING AVERAGE OF THE DATA (SHOWN BY MEANS OF A BROKEN LINE). THE DOT AND DASH LINES AT EITHER END OF THE 9-YEAR MOVING AVERAGE MARKED A REPRESENT THE 9-YEAR MOVING AVERAGE VALUES OBTAINED BY USING ADJUSTED VALUES FOR THE CIVIL WAR AND WORLD WAR II PERIODS. THE DOTTED LINES AT EITHER END OF THE 18-YEAR MOVING AVERAGE MARKED A' REPRESENT THE 18-YEAR MOVING AVERAGE VALUES OBTAINED BY USING ADJUSTED WAR VALUES.

Fig. 3

The Liabilities of Commercial and Industrial Failures in the U.S. 1857–1950, adjusted for Civil War and World War II distortions, smoothed by a 9-year geometric moving average, and expressed as percentages from their 18-year geometric moving average.



This leaves three complete waves, measured from crest to crest on which to base our conclusions.

Certainly three successive waves, coming at about the same time interval from each other, could occur with the greatest of ease in any series of figures as the result of three separate and distinct causes. In other words, as the result of " chance. "

Of course to have the four successive crests spaced with such exact uniformity would be a bit unusual if there were no underlying rhythmic force, but even so, this regularity, and even the waves themselves, would normally be regarded as mere coincidence if it were not for the fact that a rhythm of this exact length seems to be present over long periods of time in other economic time series,[6] and in natural time series as well.[6] Also, and this fact may have especial significance, in the other series the turning points come at the same times.[6]

It is this coincidence of time span and of timing, and not by themselves the occurrence of three fairly regular waves, that makes the observed behavior worthy of being measured and recorded.

If, in years to come, after the present distortions have had an opportunity to correct themselves, we find waves of about 17 2/3 years reappearing, and if these waves prove to be in phase with the waves of 1870 to 1940, we will at that time have grounds for wondering if the 17 2/3-year rhythm in the liabilities of commercial and industrial failures may not have significance. In the meantime, we can merely wait.

TABLE 1

THE LIABILITIES OF COMMERCIAL AND INDUSTRIAL FAILURES IN THE UNITED STATES, 1857-1950 IN MILLIONS OF DOLLARS

YEAR	LIABILITIES (000 OMITTED)	YEAR	LIABILITIES (000 OMITTED)	YEAR	LIABILITIES (000 OMITTED)	YEAR	LIABILITIES (000 OMITTED)	YEAR	LIABILITIES (000 OMITTED)	YEAR	LIABILITIES (000 OMITTED)
1857	$292	1873	228	1889	149	1905	103	1921	627	1936	*203
1858	96	1874	155	1890	190	1906	119	1922	624	1937	*183
1859	64	1875	201	1891	190	1907	197	1923	540	1938	*247
1860	80	1876	191	1892	114	1908	222	1924	543	1939	183
1861	207	1877	191	1893	347	1909	154	1925	444	1940	167
1862	23	1878	234	1894	173	1910	202	1926	409	1941	136
1863	8	1879	98	1895	173	1911	191	1927	520	1942	101
1864	9	1880	66	1896	226	1912	203	1928	490	1943	45
1865	18	1881	81	1897	154	1913	273	1929	483	1944	32
1866	54	1882	102	1898	131	1914	358	1930	668	1945	30
1867	97	1883	173	1899	91	1915	302	1931	736	1946	67
1868	64	1884	226	1900	138	1916	196	1932	928	1947	205
1869	75	1885	124	1901	113	1917	182	1933	503	1948	235
1870	88	1886	115	1902	117	1918	163	1934	*334	1949	308
1871	85	1887	168	1903	155	1919	113	1935	*311	1950	248
1872	121	1888	124	1904	144	1920	295				

SOURCES:

1857-1899 STATISTICAL ABSTRACT OF THE U. S., 1908, P. 765.
1899-1944 STATISTICAL ABSTRACT OF THE U. S., 1949, P. 525*.
1945-1948 STATISTICAL ABSTRACT OF THE U. S., 1949, P. TWT AS CORRECTED BY FOOTNOTE ON PAGE S-4 OF FEBRUARY 1950 SURVEY OF CURRENT BUSINESS.
1949 SURVEY OF CURRENT BUSINESS FOR FEBRUARY 1950, P. S-4
1950 SURVEY OF CURRENT BUSINESS FOR MARCH 1951, P. S-4.

*VALUES FOR 1934-38 MUST BE INCREASED BY 9 1/5% TO MAKE THEM COMPARABLE, AS NEARLY AS MAY BE, WITH THE VALUES BEFORE AND AFTER THESE YEARS. ADJUSTED VALUES ARE 365, 340, 222, 200, AND 270.

REFERENCES

1 STATISTICAL ABSTRACT OF THE UNITED STATES, 1908.
2 STATISTICAL ABSTRACT OF THE UNITED STATES, 1949.
3 SURVEY OF CURRENT BUSINESS, FEBRUARY 1950.
4 DEWEY, EDWARD R., CYCLE ANALYSIS: THE MOVING AVERAGE, TECHNICAL BULLETIN NO. 4, PUBLISHED 1950 BY THE FOUNDATION FOR THE STUDY OF CYCLES.
5 CROXTON, FREDERICK E., AND COWDEN, DUDLEY J., "APPLIED GENERAL STATISTICS, PRENTICE HALL, INC., NEW YORK, 1941.
6 DEWEY, EDWARD R., UNPUBLISHED RESEARCH NOW BEING PREPARED FOR PUBLICATION, BY THE FOUNDATION FOR THE STUDY OF CYCLES.

CYCLES IN CANADIAN PACIFIC RAILWAY FREIGHT TRAFFIC

G. Meredith Rountree
Canadian Pacific Railway
Montreal, P. Q.

THE 9-MONTH RHYTHM

In 1942, in co-operation with the Foundation for the Study of Cycles, the writer made a cyclical analysis of the fluctuations in the freight traffic of the Canadian Pacific Railway. The purpose of this analysis was to determine whether the fluctuations could be broken down into a series of regular periodicities, having in mind the value in forecasting if these periodicities continued. Two of the rhythms developed in this analysis were approximately nine months and thirty-three months, respectively, from trough to trough, and these periods are short enough in relation to the time that has elapsed since they were developed to permit of some evaluation of the results of the analysis. The purpose of this report, and the one which follows, is to describe the process by which these rhythms were determined and the extent to which they have continued.

THE BASIC DATA

In approaching a study of railway freight traffic, there are several items that could be chosen for analysis, such as revenues, tons, and ton-miles. In this study it was decided to analyze the physical volume of traffic so as to eliminate the effect of rate changes. Revenues were therefore discarded. Of the items measuring physical volume, ton-miles were chosen. Ton-miles are the product of the tonnage carried and the miles hauled, and since these statistics are compiled by individual shipments, the total may be represented by the formula $\Sigma(x \cdot y)$, where x is the tonnage of each individual shipment and y the distance in miles that tonnage is hauled. Ton-miles were chosen because in many aspects of railroading the length of the haul is just as important as the tonnage. The long haul traffic is, of course, weighted more heavily in the ton-miles than is the short haul traffic.

It was also decided to use monthly data in order to achieve greater exactitude in determining both the period and the timing. Monthly figures of ton-miles for all the lines of the Company were available from July 1903. Since the study was undertaken in 1942, there were 462 months available to the end of 1941. In connection with the stage of growth, it may be noted that the first month in the series was approximately twenty-two years after the formation of the Company and eighteen years after the completion of its main line between Montreal and Vancouver.

The basic data are shown plotted on semi-logarithmic scale in Figure 1, with the figures for the years 1942 to 1949, which were not available at the time the study was made, added.

THE SEASONAL

The first plotting of the basic data revealed two significant facts — that there had been substantial growth in the Company's business during the period under review, and that the traffic was subject to very pronounced seasonal fluctuations. While the growth would not disturb the calculations, the seasonal fluctuations were so pronounced that it was clear that the analysis could not proceed until the seasonal had been isolated and the figures adjusted for it.

In order to isolate the seasonal fluctuations, insofar as possible, from the trend and cyclical fluctuations, the basic data were expressed as percentage deviations from their twelve-month arithmetic moving average (centered). Examination of these deviations (Fig. 2) revealed that the amplitude and timing of the seasonal fluctuations had varied considerably during the period, and that a constant pattern would not provide a satisfactory adjustment. For example, the amplitude of the deviations above the moving average varied from 21.3% in 1911, to 93.8% in 1922, 37.9% in 1934, and 18.3% in 1940. It was imperative, therefore, to describe the seasonal fluctuations by means of a changing pattern for purposes of adjustment.

Considerable time was spent in experimenting with various methods of determining the changing seasonal pattern. Among others, a 6-section moving average (centered) was tried. The section moving average is made up of (in the case of a seasonal) separate moving averages for the Januarys, the Februarys, etc. In addition to the 6-section moving average, a 3-section moving average was also tried. Both of these had their deficiencies. The former seemed to give too much weight to the outlying years, while the latter produced a pattern that seemed too irregular. A combination of the two was found to provide a better description of the seasonal fluctuations in each year. Combining the 6-section and 3-section moving averages had the effect of producing a 7-section moving average weighted as follows:

$$a + 2b + 6c + 6d + 6e + 2f + g$$

This method of calculation was used for the series up to the years immediately preceding World War II. It could not be used later than that because the war produced an abrupt change

in the seasonal. The first full year of war — 1940 — saw the amplitude reduced to a fraction of what it was in 1939. Since the war years, clearly, could not be used in calculating the pre-war pattern, the number of years included in the calculations was gradually reduced in the years following 1936, until in 1939 only four years were included. The war years were treated separately. The pattern so developed is shown in Figure 3. As in the case of Figures 1 and 2, the data are plotted to the end of 1949. It will be noted that there has been some increase in amplitude since the end of the war, and that in the post-war period a uniform pattern, based on the years in question, has been assumed.

While the physical background of this changing seasonal pattern is not of immediate interest, for those readers whose curiosity has been aroused, it may be mentioned briefly that the changes are largely associated with the grain traffic. They reflect the expansion in production of wheat for export during World War I and the twenties, the droughts of the thirties, the shutting off of European markets by World War II and the industrial development of Canada (accelerated by the war) which reduces the relative importance of grain in Canadian Pacific traffic.

DETERMINATION OF THE PERIOD

When the seasonal pattern had been calculated, the ton-miles were adjusted for seasonal fluctuations by dividing the value for each month by the pattern index for that month and multiplying by 100. The seasonally-adjusted figures are shown in Figure 4. The plotting of these data immediately revealed that there were other short term fluctuations besides the seasonal. These were not so pronounced as the seasonal, but they were of sufficient magnitude to make it clear that, whether rhythmic or not, knowledge of their nature was essential to any further analysis of the data.

By inspection, it was ascertained that the average period of these fluctuations was somewhere in the neighbourhood of nine months. This preliminary choice of a length of nine months was not pure chance. Even a cursory examination of the data plotted in Figure 4 will indicate that the modal length is less than a year. Likewise, it is clearly longer than six months. But the real reason for suspecting a period of nine months and deciding to test it was that a rhythm of approximately this length had been found in other series.

Since the period of the rhythm was believed to be approximately 9 months, and since it had originally been decided to conduct the analysis in terms of deviations from moving averages, a 9-month arithmetic moving average and the percentage deviations from it were calculated. Later in this report it will be demonstrated that the use of a 9-month moving average did not introduce a 9-month rhythm into the fluctuations. Suffice it to say at this point that a 9-month moving average was used for the same reasons that a 12-month moving average was used in connection with the seasonal pattern. The choice of a different length for the moving average would not have affected the timing of the fluctuations in the deviations but would have either minimized or exaggerated the amplitude.

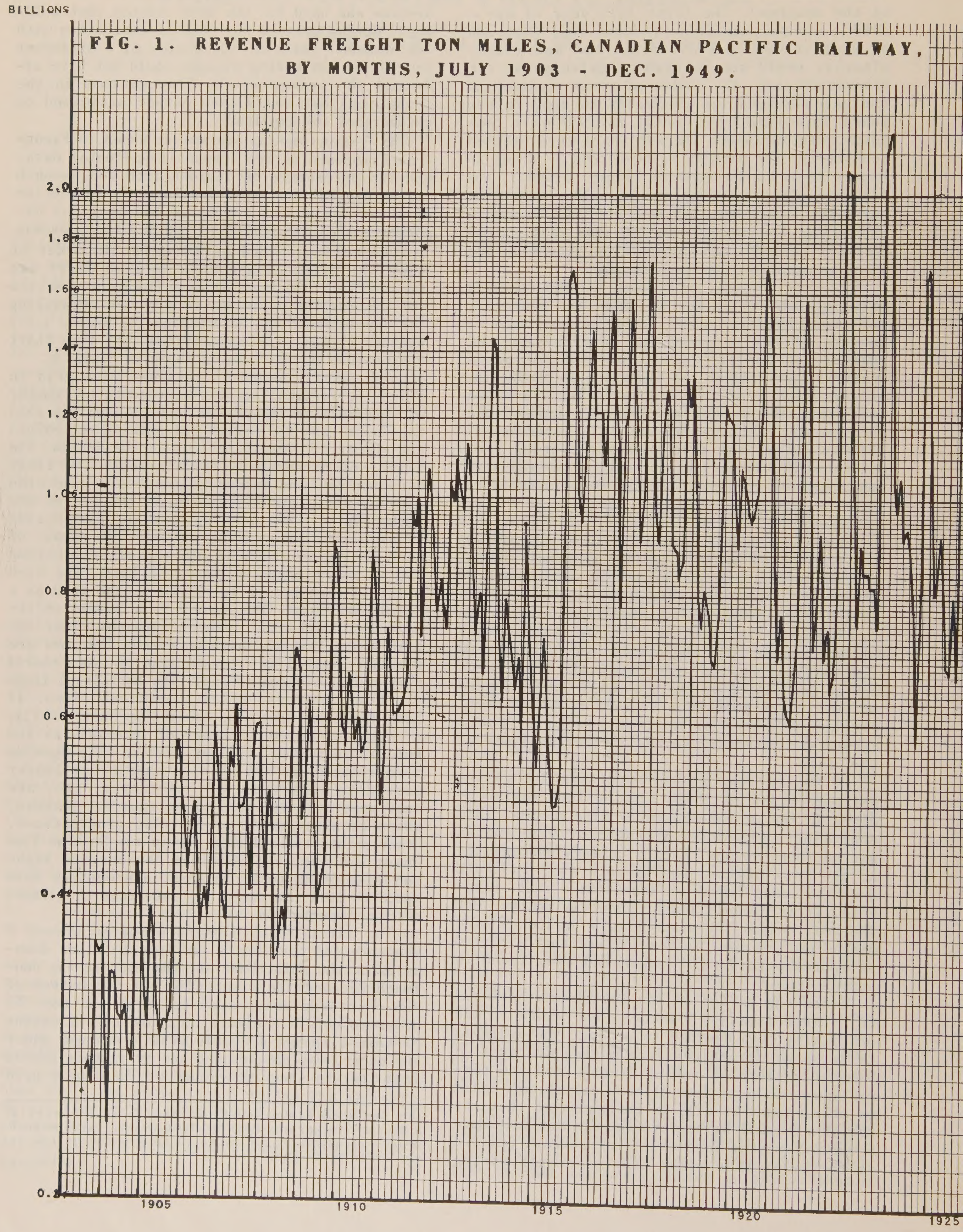
The 9-month moving average is shown in Figure 4 superimposed on the seasonally-adjusted data, and the percentage deviations from the 9-month moving average are shown in Figure 5. Inspection of these deviations supported the original hypothesis that the period of the fluctuations was in the neighbourhood of 9 months. In order to test the hypothesis a Hoskins Time Chart was constructed. The Hoskins Time Chart is a device for testing the existence of a rhythm, measuring its exact length and determining its shape, i.e., whether or not it is symmetrical. The time chart constructed in this case is shown in Figure 6.

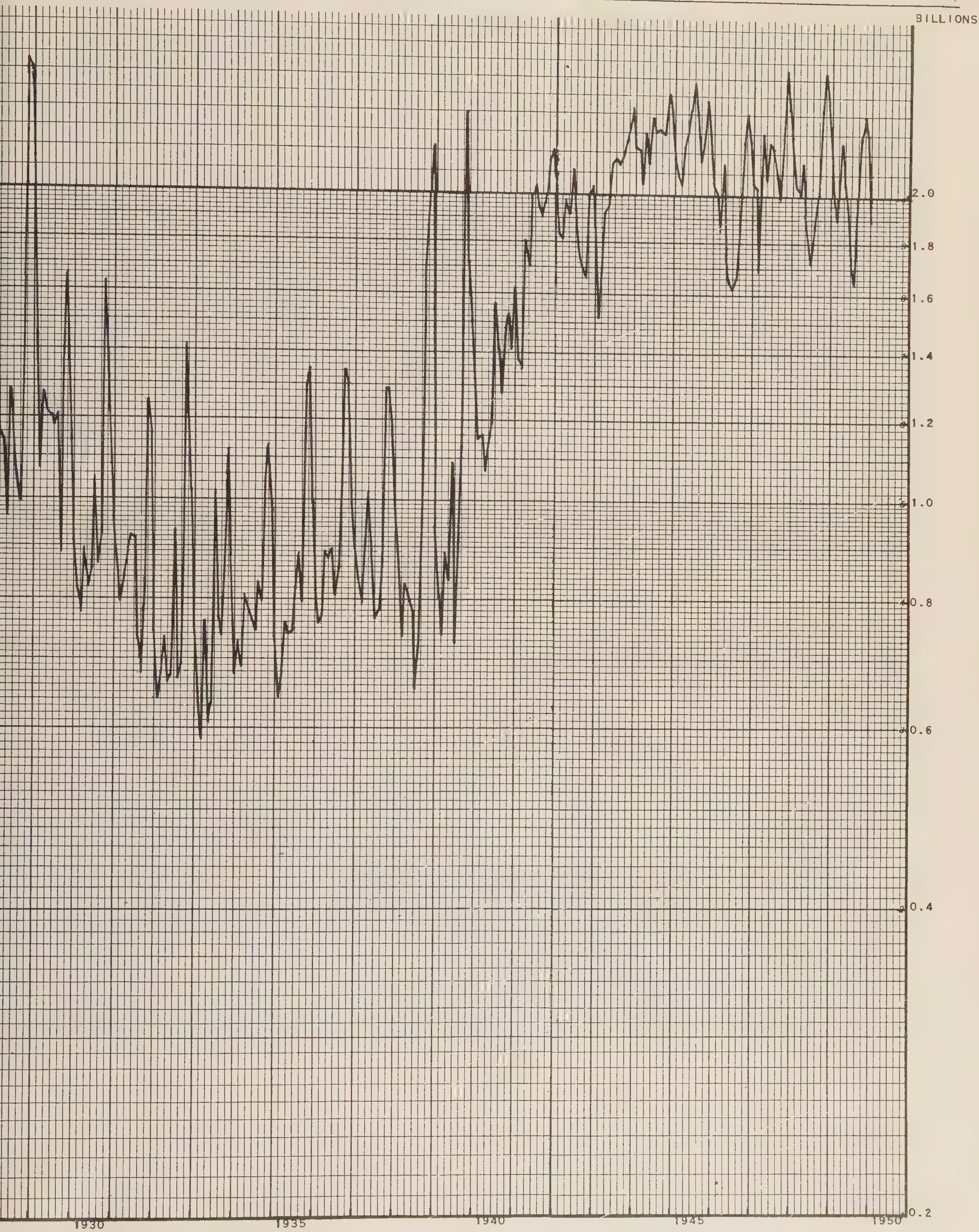
The usual time chart consists of a grid in which the vertical spacing represents the number of intervals in the period to be tested (in this case nine) and the horizontal spacing represents the number of 9-month periods in the series. The first column on the grid represents the first nine months, the second column the second nine months, etc. Thus the months in the series are broken up into sections of nine and placed side by side. The base month, or starting point, of each period is shown at the top of each column and is represented on the grid by 0. The high point in each period is marked on the grid as a solid horizontal line opposite the number on the left that marks the number of months after the base month that the high occurred. The lows are similarly marked by a broken line (in work charts they would be shown in red). The horizontal lines are then connected up with vertical lines. If both highs and lows tend to line up horizontally, a rhythm of the same number of intervals as the grid is indicated. If they tend to slip upwards or downwards on the grid, a shorter or longer period is indicated. If, of course, they are scattered over the grid in no apparent pattern, there is no evidence of rhythmic fluctuations. Other points to be looked for in the Hoskins Time Chart are whether the space between the highs and lows tends to be uniform, and whether this space is half the number of intervals thus indicating symmetry (1).

The first 9-month chart prepared showed a tendency for both highs and lows to slide downwards on the grid. However, the picture was confused because the lines slid off the bottom of the chart and reappeared again at the top. In order to obtain a clearer picture of the extent of this slippage a double grid, with one under the other, was constructed and it is this double grid that is shown in Figure 6. The double grid

(1) For a fuller discussion, see "Cycle Analysis: A Description of the Hoskins Time Chart" by Edward R. Dewey, Technical Bulletin No. 3 of the Foundation for the Study of Cycles.

FIG. 1. REVENUE FREIGHT TON MILES, CANADIAN PACIFIC RAILWAY, BY MONTHS, JULY 1903 - DEC. 1949.




BILLIONS
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1930
1935
1940
1945
1950

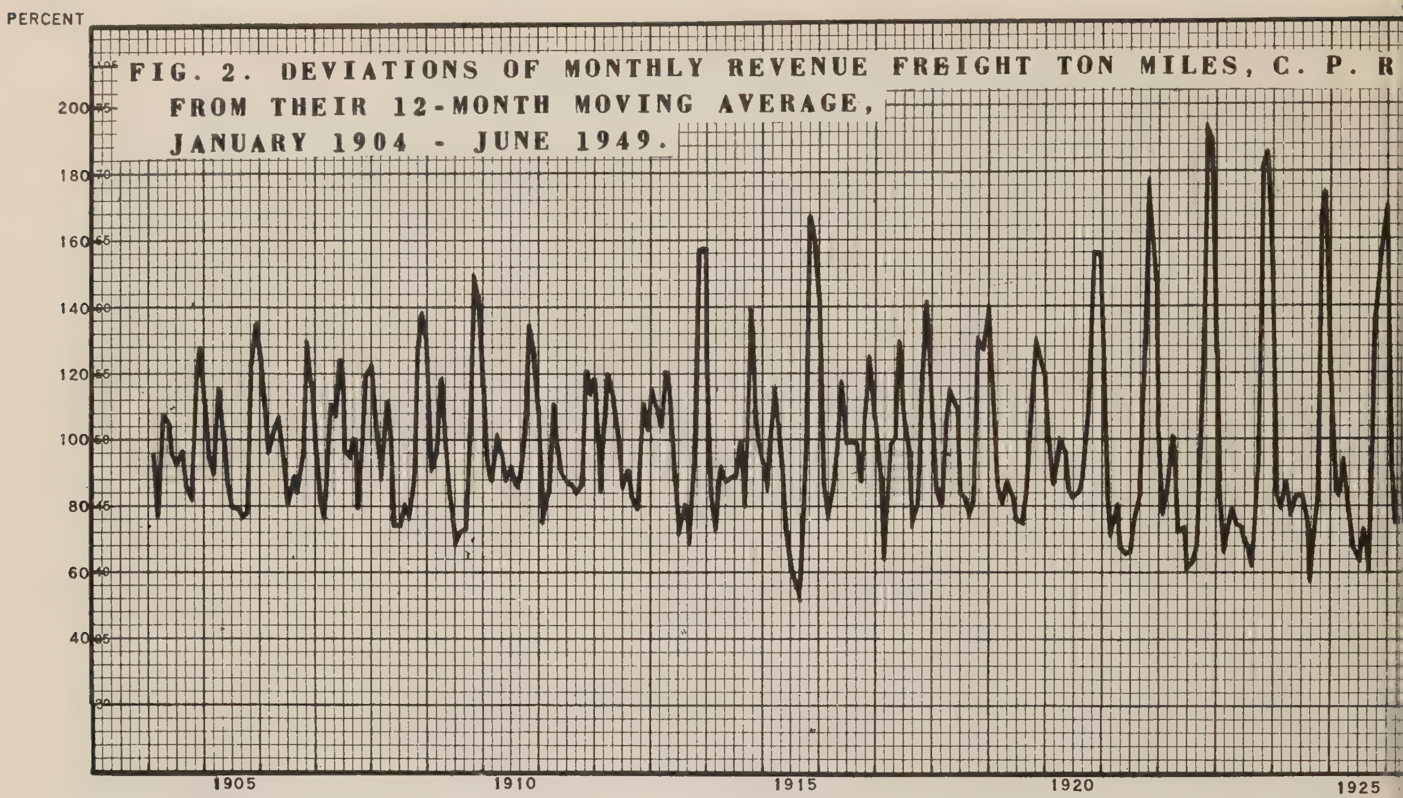


FIG. 2. DEVIATIONS OF MONTHLY REVENUE FREIGHT TON MILES, C. P. R
FROM THEIR 12-MONTH MOVING AVERAGE,
JANUARY 1904 - JUNE 1949.

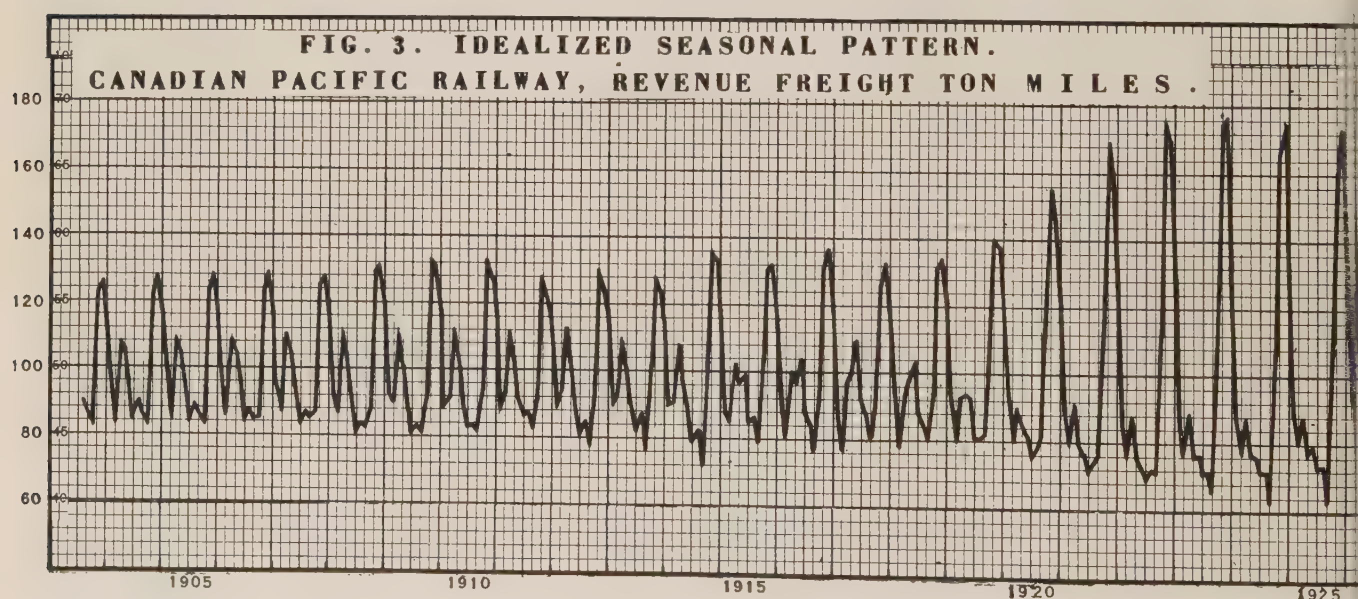
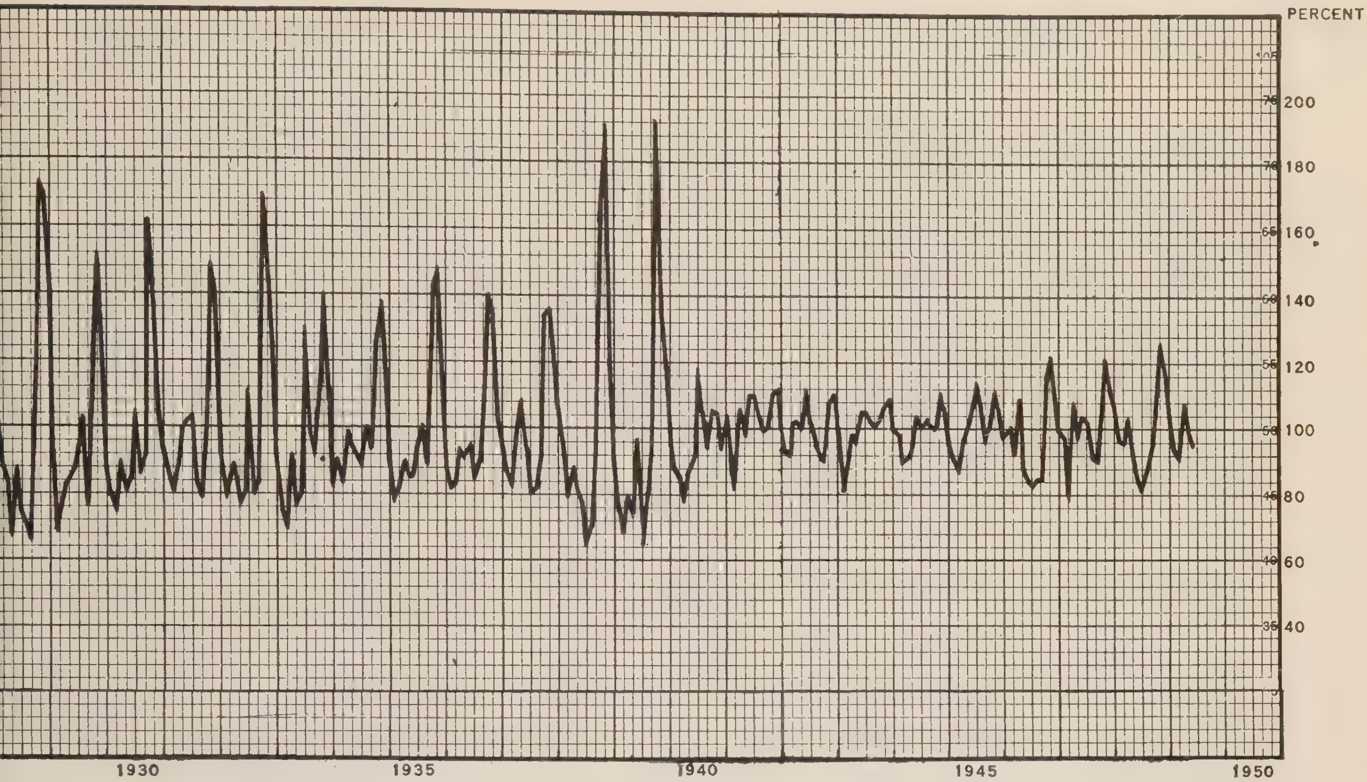


FIG. 3. IDEALIZED SEASONAL PATTERN.
CANADIAN PACIFIC RAILWAY, REVENUE FREIGHT TON MILES.


PERCENT
200
180
160
140
120
100
80
60
40
1930
1935
1940
1945
1950


180
160
140
120
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80
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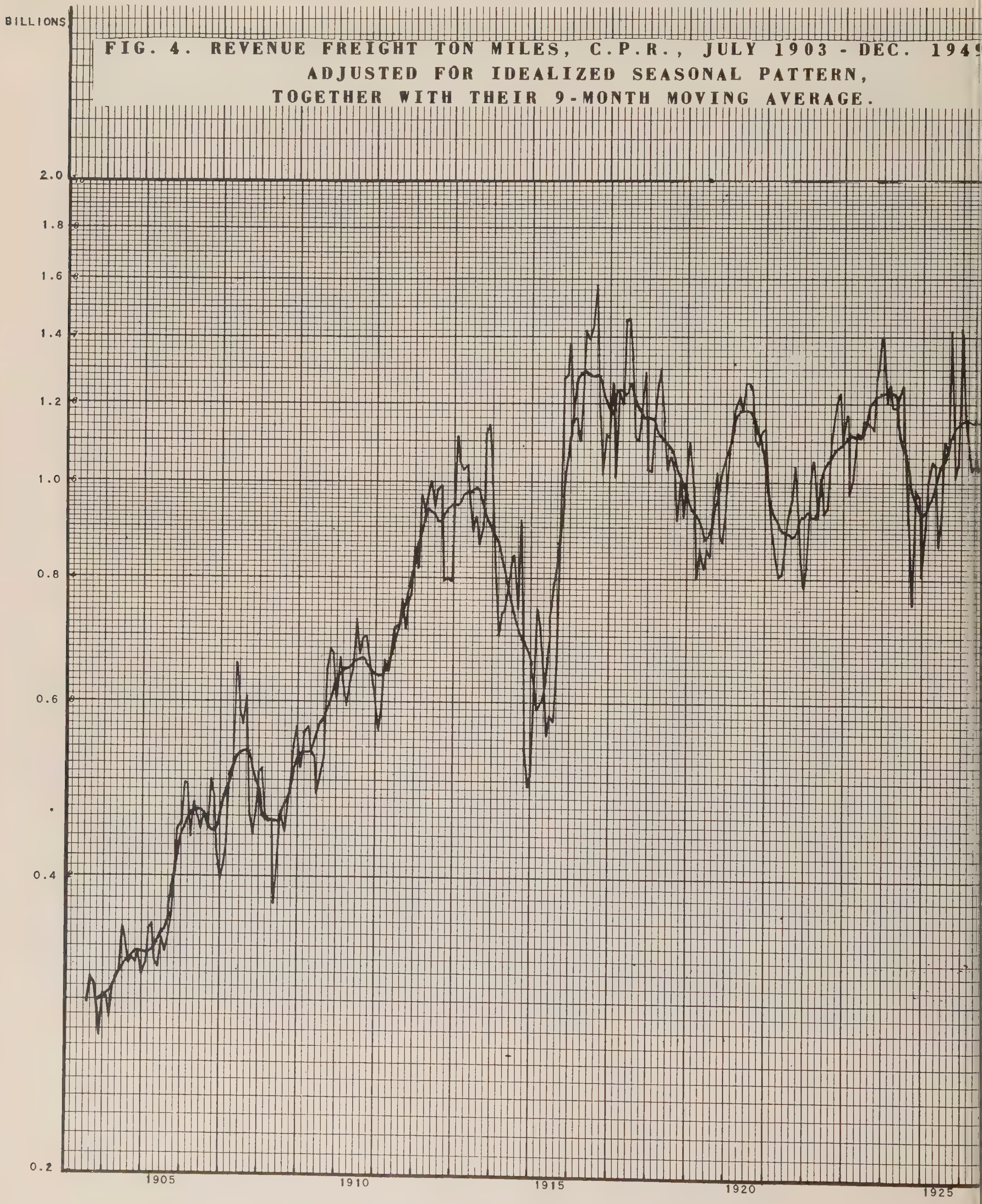
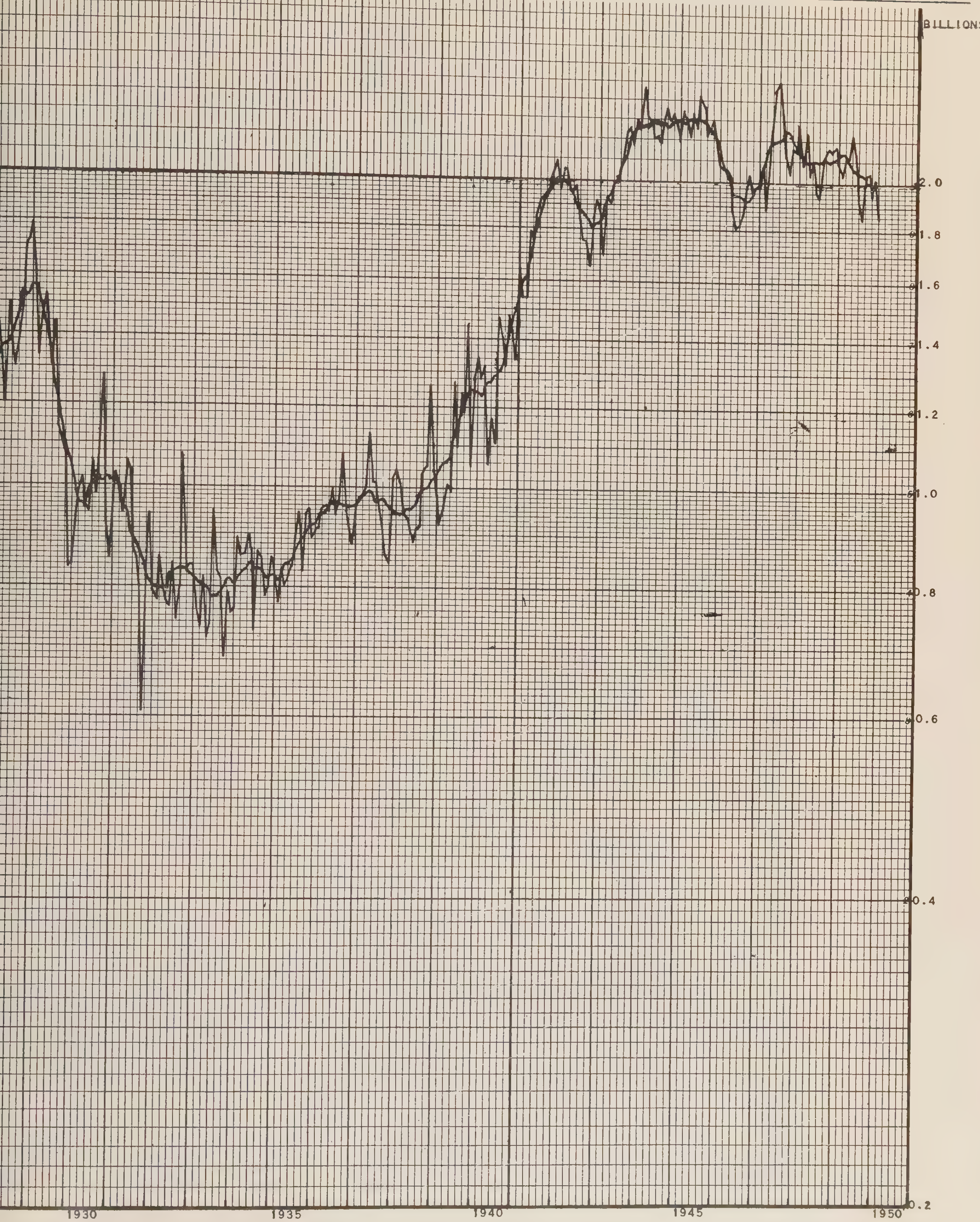
1930
1935
1940
1945
1950


BILLIONS
FIG. 4. REVENUE FREIGHT TON MILES, C.P.R., JULY 1903 - DEC. 194
ADJUSTED FOR IDEALIZED SEASONAL PATTERN,
TOGETHER WITH THEIR 9-MONTH MOVING AVERAGE.
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1905
1910
1915
1920
1925


BILLIONS
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1930
1935
1940
1945
1950

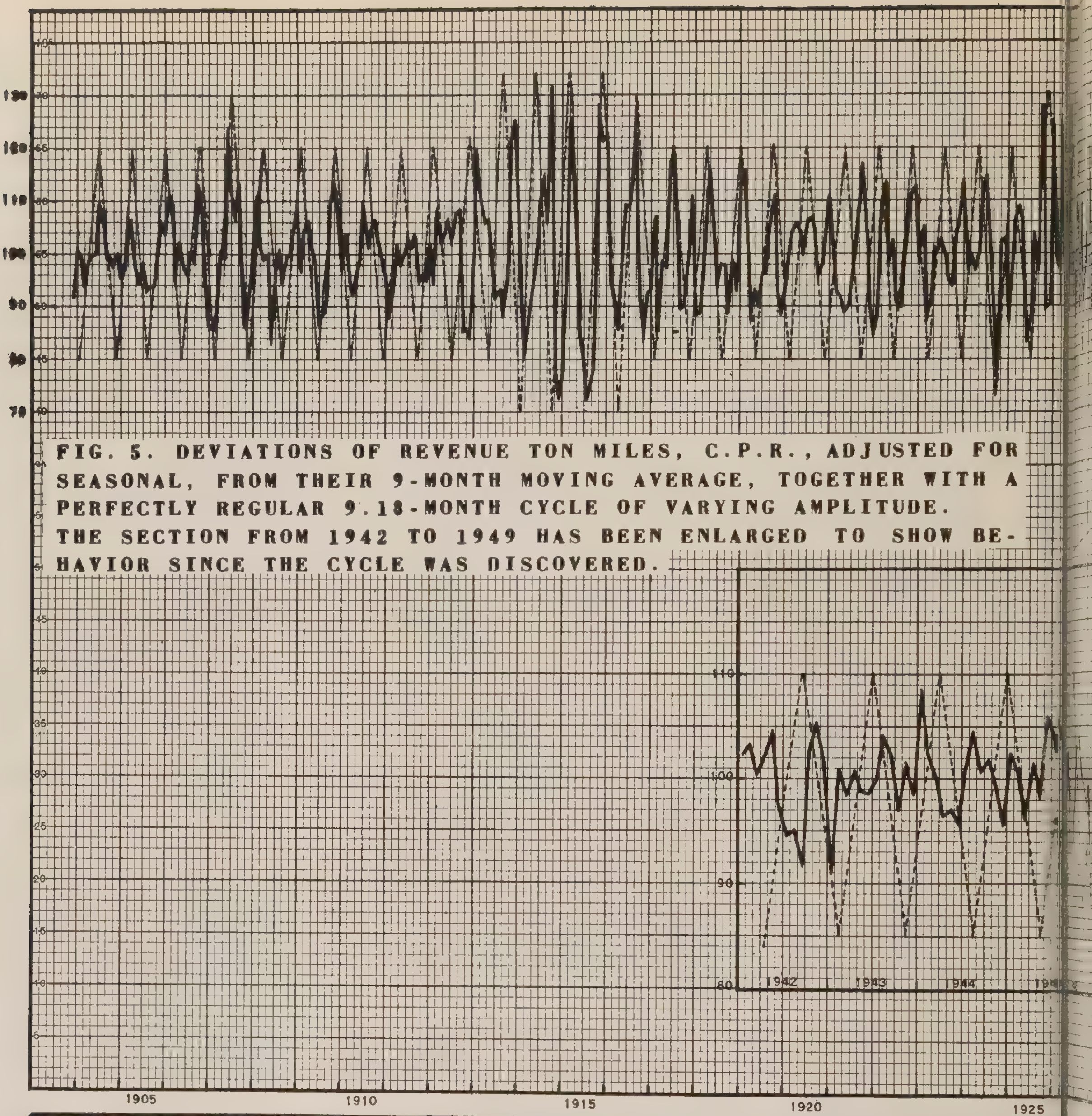


FIG. 5. DEVIATIONS OF REVENUE TON MILES, C.P.R., ADJUSTED FOR SEASONAL, FROM THEIR 9-MONTH MOVING AVERAGE, TOGETHER WITH A PERFECTLY REGULAR 9.18-MONTH CYCLE OF VARYING AMPLITUDE. THE SECTION FROM 1942 TO 1949 HAS BEEN ENLARGED TO SHOW BEHAVIOR SINCE THE CYCLE WAS DISCOVERED.

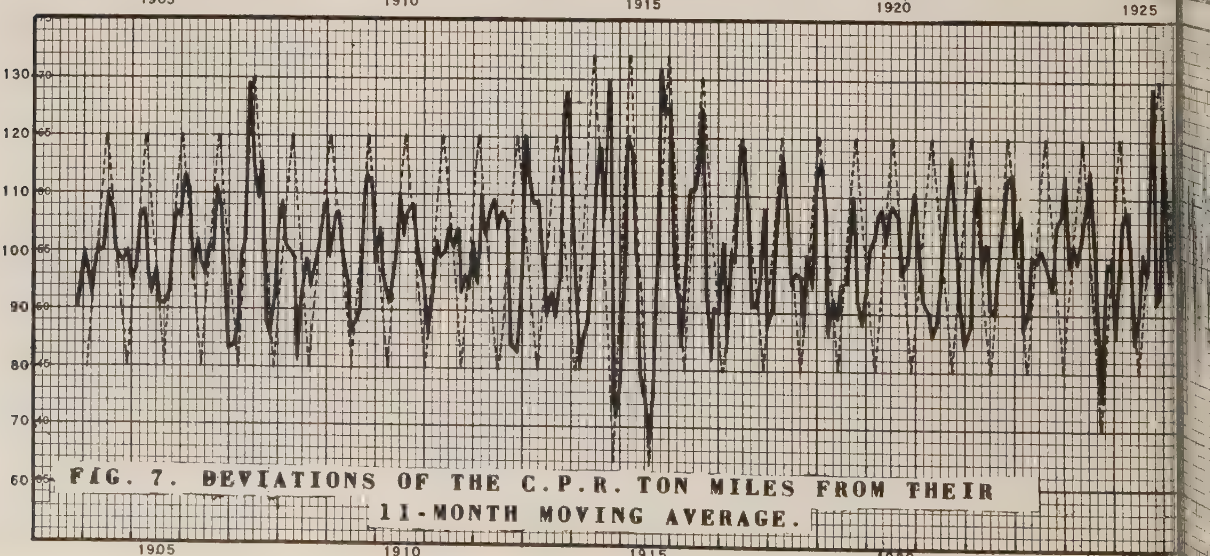


FIG. 7. DEVIATIONS OF THE C.P.R. TON MILES FROM THEIR 11-MONTH MOVING AVERAGE.

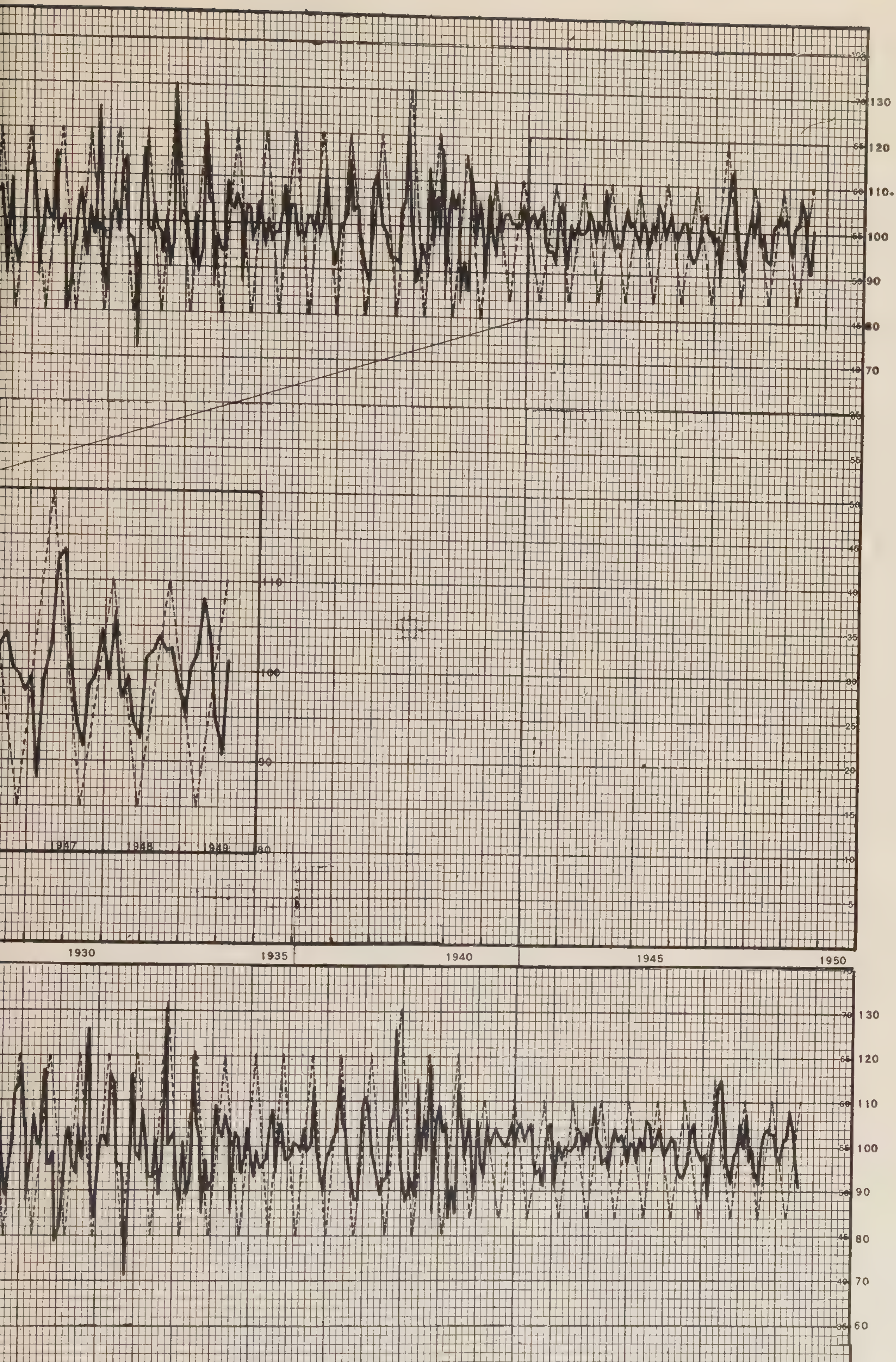
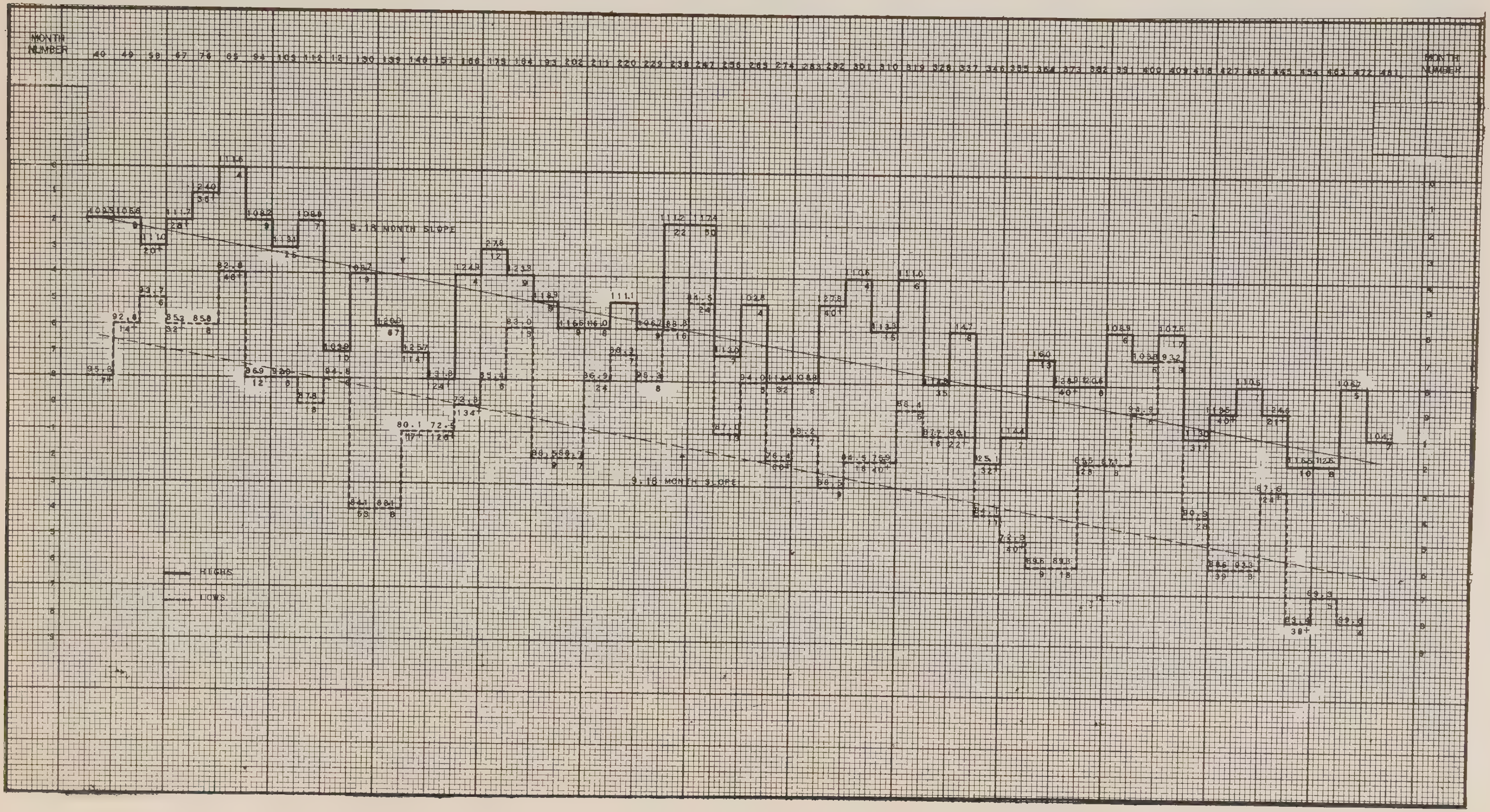

130
120
110
100
90
80
70
110
100
90
80
1947
1948
1949
1930
1935
1940
1945
1950
130
120
110
100
90
80
70
60
1930
1935
1940
1945
1950

FIG. 6. A 9-MONTH TIME CHART OF THE DEVIATIONS OF THE C.P.R. TON MILES FROM THEIR 9-MONTH MOVING AVERAGE.



gave two possible locations for the highs and lows in each cycle. For example, the highs and lows in the second cycle could be shown as following the first cycle either in the second column of the first grid or in the first column of the second grid. Thus, when the lines slid off the bottom of the first grid they could be continued on in the second.

When the time chart was constructed in this fashion it showed that, while there were variations in timing, there was a tendency for both highs and lows to line up on a downward slant. This indicated a rhythm with a period somewhat longer than nine months. The extent of the slippage, and therefore the extent to which the indicated length exceeded nine months, is shown by the straight slanting lines that run through both highs and lows. The slope of these lines represents .18 of a month per cycle. On this basis the period was fixed at 9.18 months.

Those who have never calculated rhythms for themselves may consider this specious accuracy. However, a little reflection will reveal that with a period as short as this an effort to measure the length as accurately as possible is both necessary and practicable. If a 9-month rhythm had been chosen instead of 9.18, this would have made a difference in timing of 4½ months in 25 cycles. After 19 years, therefore, these two rhythms would be in inverse phase. Since there are 38 years in the series, obviously it would be futile to deal with a period of 9 months if it was actually 9.18. Even an error of .05 in the period would make a difference of nearly 2½ months, or 27%, over the whole series.

THE TIMING

Having fixed the period at 9.18 months, there remained to be determined the timing, amplitude and shape of the ideal rhythm.

The timing and amplitude were calculated from the deviations from the 9-month moving average in the same way that a uniform seasonal pattern is calculated. The series was divided up into sections of the same number of months as the period of the rhythm and a table was constructed with the same number of columns. The value for the first month in each section was entered in the first column of the table, the value for the second month in each section was entered in the second column, etc. The only difference in the technique from the calculation of a seasonal resulted from the fact that we were dealing with a period that involved a fraction of a month. In view of this, the table was constructed with ten columns and a value was entered in the tenth column whenever the number of lines used multiplied by .18 produced a decimal that exceeded .50. Thus, the values for nine successive months were entered in the first nine columns of the first line and the same procedure was followed with the second line. On the third line, however, since .18 x 3 = .54, values were entered in all ten columns. Successive lines of nine then followed until the decimals again accumulated to more than a half month. This had the effect of producing a 9.18-month table even though values for whole months were being used.

The averages of the values in the nine complete columns were calculated and plotted. This curve gave evidence of a flat top and a pointed bottom. This would be the characteristic of a cycle with an odd number of intervals in which the low occurred in the middle of an interval, and therefore produced a value for that interval lower than those on either side of it, and in which the peak occurred in between two intervals and therefore produced two successive equal values. For this reason the position that showed the lowest average value was chosen as the timing of the low.

The timing of the peak was partly dependent on the shape. Both the time chart and the average cycle developed from the table gave evidence of symmetry. Certainly, at least, there was no definite evidence of asymmetry. The high was therefore assumed to be half the period distant from the low.

The timing of the ideal rhythm is shown by a zig-zag superimposed on the deviations from the 9-month moving average in Figure 5. While the scale of this chart is small, it is possible by careful inspection to compare the timing of the actual highs and lows with the ideal. It should be kept in mind, though, that whereas Figure 5 shows the data through 1949, the last eight years were not available at the time the analysis was made. A tabular comparison of the timing of the highs with the ideal follows:

Timing of Highs

	Number
Ideal timing or ½ month one way or the other	22
1½ months one way or the other	11
Total in phase	33
2½ months one way or the other	9
3½ " " " " " "	6
4½ " " " " " "	2
Total out of phase	17
Grand Total	50

This table represents an objective test in that the actual highs were counted by the method developed by Mr. Hoskins without any allowance whatever for the presence of accidental or non-recurring fluctuations. These other influences must be present and create distortions. Since the ideal high occurs in between two intervals, it has not been possible to show the number with ideal timing. However, it will be noted that the mode is in the two months centering around ideal, and that thirty-three out of the fifty highs occurred in the four month period centering around ideal. Actually this 4-month period is slightly less than the positive phase which is approximately 4½ months, but it is as close as it is possible to represent it in terms of whole months. In addition, it will be noted that the figures

in the table become smaller as it progresses, which is further evidence of the tendency to center around ideal timing.

A similar tabulation of the timing of the lows follows:

Timing of Lows

	Number
Ideal timing	8
1 month one way or the other	18
2 months one way or the other	10
Total in phase	36
3 months one way or the other	8
4 " " " " " "	1
5 " " " " " "	3
6 " " " " " "	1
7 " " " " " "	1
Total out of phase	14
Grand Total	50

In view of the fact that in the table of highs the positive phase was represented as being four months, the negative phase is shown here as being five months, or slightly more than the proper figure of approximately 4½. It will be noted that eight of the lows showed ideal timing, while thirty-six out of fifty occurred in the 5-month period centering around ideal. Once again it will also be noted that the figures tend to become smaller as the table progresses.

In attempting to interpret anything new, the observer always looks for something familiar against which to measure it. In this case, the only familiar phenomenon that even faintly resembles the 9-month rhythm is the seasonal. Now, for a variety of reasons, the seasonal and the 9-month rhythm are not strictly comparable, but since it is the only comparison available, it may give some perspective to apply to the seasonal the same test of timing that was applied to the 9-month rhythm. Let us assume that we did not know enough about the seasonal to be able to calculate a changing pattern, but were forced to assume a constant pattern based on the average of the whole series. How would the highs and lows compare with the average? The following table makes the same comparison as was made for the 9-month rhythm:

Timing of Seasonal

	Number of Highs	Number of Lows
Ideal timing	16	11
1 month out one way or the other	17	3
2 months " " " " " "	2	8
3 " " " " " " "	-	1
	35	23
3 months out one way or the other	-	
4 " " " " " " "	1	1
5 " " " " " " "	2	4
6 " " " " " " "	-	10
	3	15
Grand Total	38	38

This table has a number of deficiencies. In the first place, the figures have been grouped according to whether the turning points fell in one half of the period or the other, as though the seasonal were symmetrical. Actually it is not. The high occurs in October and the actual low in August has been used rather than the symmetrical low. For another thing, if we were analyzing the seasonal in this fashion we would probably not deduce a simple wave, but would assume a subsidiary peak in the spring. In view of the close concentration of the highs and the wide dispersion of the lows, the assumption of symmetry does not have much effect on the general impression created by the table. The assumption of a simple wave is probably a more serious deficiency. Nevertheless, the table does serve to demonstrate that even a rhythm that is so regular that it can be observed by the man in the street, does exhibit deviations from the average pattern. It will be noted that the 3-month deviation from ideal timing has been included in the " in phase " group for the low and in the " out of phase " group for the high. This is because the months must be divided seven and five, and the procedure of assigning slightly less than half the period to the high was followed in connection with the 9-month rhythm. However, only one low falls in this area and no highs.

Since there are fifty cycles in the 9-month rhythm and only 38 in the seasonal, expressing the figures in terms of percentages of the total may assist in comparing the two.

	Percent of Total 9-month Rhythm	Percent of Total Seasonal
Highs		
In phase*	66	92
Out of phase*	34	8
	100	100
Lows		
Ideal timing	16	29
In phase*	72	61
Out of phase*	28	39
	100	100

This comparison is not intended to be taken too literally. There are many objections that could be raised to it. It does not prove anything but it is not offered as proof. It has been included only to demonstrate that perfect timing is not to be expected in rhythms, and that its absence does not disprove the existence of a rhythm or invalidate the usefulness of a knowledge of it.

THE AMPLITUDE

The mean amplitude of the 9.18-month rhythm expressed in terms of percentage deviations is 4.8. This mean amplitude is calculated from the 9.18-month table, making allowance for the fact that the high occurs between two intervals, and equalizing the positive and negative deviations.

* IN VIEW OF THE LACK OF SYMMETRY IN THE SEASONAL, THE EXPRESSIONS " IN PHASE " AND " OUT OF PHASE " DO NOT PROPERLY APPLY TO THE SECOND COLUMN.

It is expressed in this manner because the experience of the Foundation for the Study of Cycles has been that rhythms tend to show equal percentage deviations above and below the zero line. The median amplitude for the period 1904 to 1941, once again equalizing the positive and negative deviations, is ± 12.7. It will be noted that this amplitude is considerably less than the seasonal.

DEVIATIONS FROM 11-MONTH MOVING AVERAGE

Earlier in this report reference was made to the necessity of dealing with a rhythm in terms of deviations from a moving average of the same length as that of the rhythm. The theoretical basis for this is that a 9-month moving average of a perfectly regular 9-month rhythm will be a straight line and therefore the deviations of the rhythm from this moving average will be exactly the same as the rhythm itself, whereas a moving average of more or less than nine months through a perfectly regular 9-month rhythm will be a wavy line and therefore the deviations of a 9-month rhythm from it will show either a greater or lesser amplitude than the rhythm. A complete discussion of the theory of the use of moving averages is given in " Cycle Analysis: The Moving Average " by Edward R. Dewey, Technical Bulletin No. 4, Foundation for the Study of Cycles. There is, therefore, no need to go into all the details of the theory here, but a practical demonstration that a choice of a moving average of a different length would not have affected the timing of the 9-month rhythm may be of interest.

In Figure 7 the deviations of the ton-miles adjusted for seasonal from their 11-month moving average are shown. It is possible to compare the fluctuations shown in this chart with those shown in Figure 5. To assist in this comparison, the same 9.18-month zig-zag, which appears in Figure 5, has been repeated in Figure 7. Careful inspection will reveal that the turning points of both sets of deviations are exactly the same. A tabulation of the comparisons of the timing of actual highs and lows with ideal was made on the same basis as that compiled using the deviations from the 9-month moving average. The distribution of the highs and lows around the ideal is exactly the same as in the case of the deviations from the 9-month moving average. The mean amplitude calculated from the deviations from the 11-month moving average is ± 5.3 and the median amplitude is ± 13.8. These figures may be compared with the values of ± 4.8 and ± 12.7, respectively given above. Thus, if an 11-month moving average had been used instead of a 9-month moving average, exactly the same timing would have been found but the amplitude would have been slightly greater. However, this amplitude would have been exaggerated.

THE PROJECTION

As has been mentioned, this analysis of the 9-month rhythm was made in 1942, based on data for the years 1903 to 1941, and the ideal timing shown in Figure 5 for the years 1942 to 1949 is a projection determined in 1942. The extent to which the rhythm has continued can therefore be judged by comparison of this projection with the actual.

From Figure 5 it will be noted that during World War II the amplitude was greatly reduced, in fact so much so that, although a tendency towards 9-month fluctuations could be deduced, for all practical purposes the wave ceased to exist. This is the opposite of what happened in World War I. At that time the amplitude was greatly increased.

Following World War II, however, the rhythm reappeared in approximately the timing forecast. There are five complete cycles following the war. The comparison of the timing of these with the projection is given in the table below. In order to consolidate the data, the captions at the left show the wording for the lows with the wording for the highs being given in brackets.

Timing of Post-War Cycles

	Highs	Lows
Ideal timing (and ½ month one way or the other)	1	2
1 month (1½ months) one way or the other	1	-
2 months (2½ months) " " " " "	2	1
3 months (3½ months) " " " " "	-	2
Total	4	5

The amplitude of these four cycles ranged from 3.9 to 13.6 plus, and 5.1 to 11.9 minus.

THE APPLICATION

At the outset of this discussion of the 9-month fluctuations it was stated that the purpose of analyzing them in detail was partly to test the overall hypothesis of the existence of rhythmic fluctuations with a short period which gave a relatively large number of repetitions, and partly because an understanding of these fluctuations was necessary to the analysis of longer periods. It was felt that the 9.18-month rhythm exhibited sufficient regularity to indicate, at the very least, that a further investigation of the overall hypothesis was well worthwhile. It was also considered that, while the amplitude was small in relation to the seasonal, and therefore there was little to be gained in attempting to use this rhythm in forecasting, in view of the long period over which it had exhibited itself, it would be necessary to adjust for it in all subsequent analyses. The application of the 9.18-month rhythm, therefore, was the same as the application of the seasonal. Since we did not know enough about this rhythm to develop a varying pattern as was done in the case of the seasonal, it was decided to make the adjustment by means of a moving average of the length closest to 9.18 months - namely, nine months.

It was as a result of these investigations that the studies of the 33-month rhythm, which will be discussed in the second of these reports, were made entirely by analyzing the 9-month moving average of the seasonally-adjusted figures.

CYCLIC TRENDS IN ARCTIC SEASONS

by

Leonard W. Wing

Scarce indeed are past records of climatic conditions in the Arctic, and many of our hopes for studying the relations between climatic fluctuations and animal cycles depend upon known information of past years. This study concerns primarily the western Arctic, a region where no past meteorological data exist.

Freezing and thawing dates of lakes and rivers supply usable data for some types of study, particularly phenological ones. I have used these before for such a study in the Great Lakes region (**Monthly Weather Review**, 1943, 71: 149-158).

Freezing and thawing dates are the same as the closing and opening dates, respectively, of fall and spring. They give an " integrated effect " of weather, especially the lake data. Rivers may be influenced by run-off, by mixing of water, and by conditions in the upper watershed. This last point may be truer in the spring when the headwaters of northward-flowing streams open before the lower reaches than in the fall.

The opening (thawing) dates indicate the relative earliness of spring, and we may assume with logic on our side that in an early spring, the snow and ice leave early. Presumably this is also a warm spring because it is an early one.

In a like manner, the closing (freezing) dates in fall indicate the relative early or lateness of fall. This is surely a better indicator than the memory of inhabitants, which may be impressed more by a few events like notable storms than by a series of late or early seasons.

The difference between the spring thawing and fall freezing dates undoubtedly gives some measure of long or short summer seasons. In the same manner, the differences between fall freezing and spring thawing dates measure long or short winters. These indications also seem a sounder basis than a mental impression of what were long or short winters.

Many variations depend upon river size, turbidity, and watershed, as well as upon additional factors. A good example of this is shown in the data (Table 5) published by E. A. Preble (**North American Fauna**, No. 27). At the mouth of the Liard River (which has its headwaters to the South), the Mackenzie average opening date was May 6. But " above the mouth of the Liard ", the Mackenzie opening averaged May 15, a difference of nine days. This difference does not reflect the climate at the junction of the two rivers but the relatively warmer water coming down the Liard from the south and merging with the colder water coming down the Mackenzie from the east.

SPRING OPENING

I obtained data on the opening of Lewes River (Upper Yukon) at Whitehorse, Yukon Territory, (Table 1) from the White Pass and Yukon Railroad through the generosity of Mr. W. D. Gordon. The railroad, which also operates the river boats, entered these data in its journal for the simple reason that the navigation season between Whitehorse and Dawson is governed by the length of time the river is free of ice. (The exact start of spring navigation is subject to the disappearance of ice in Lake Laberge rather than in Lewes River.) The opening of Lewes River, it must also be recognized, is influenced a little by a low gate across the river at the outlet of Marsh Lake. But for lasting advantage, any collapsing of ice below the headgate by holding up the water would aid in clearing the river of ice only near the normal opening date.

The average date of opening between 1902 and 1948 was April 23 and the average closing date November 26 (Table 1). The earliest opening was March 31, 1926 and the latest May 9, 1925. The latest freezing in fall was December 23, 1944 and the earliest November 1, 1908. The extreme variations are thirty-nine days in spring and fifty-three days in fall.

The dates show four major peaks in 1905, 1915, 1926, and 1940. These average 11.7 years apart (Figure 1). There were also fifteen shorter variations that average three years apart.

I obtained the opening dates of the Yukon at Dawson from the **Dawson Weekly**. (Table 2). The average for the period was May 10, seventeen days later than at Whitehorse on the Upper Yukon (Lewes River). The earliest opening occurred April 28, 1940 and the latest May 19, 1896, a variation of twenty-one days.

Major peaks occurred about 1907, 1916, 1926, 1934, and 1942 for an average of 8.75 years apart (Figure 1). There were seventeen minor peaks between 1898 and 1947 that average 2.9 years apart.

At Fairbanks, Alaska, about 500 miles northwest of Whitehorse, I went through the office files of **Jessen's Weekly** through the generous interest of the editorial staff and tabulated out the records (Table 3) for the spring break-up of the Chena River at Fairbanks (1903-1948) and the Tanana River at Nenana (1917-1948). The Chena average spring opening date was May 6 and the same also for the 1917-1948 period when the Tanana opening averaged May 4. The earliest and latest dates for the Tanana are April 21, 1940 and May 16, 1945 for a variation of twenty-five days.

Major peaks for the Chene occurred about 1905, 1917, 1925, 1933 and 1940, for an average of 8.75 years apart (Figure 2). The short period of the Tanana shows major scales also in 1925, 1933, and 1940 for an average of 7.5 years. The fourteen short intervals 2.9 years apart for the Chena, and the twelve short ones for the Tanana averaged 2.5 years apart.

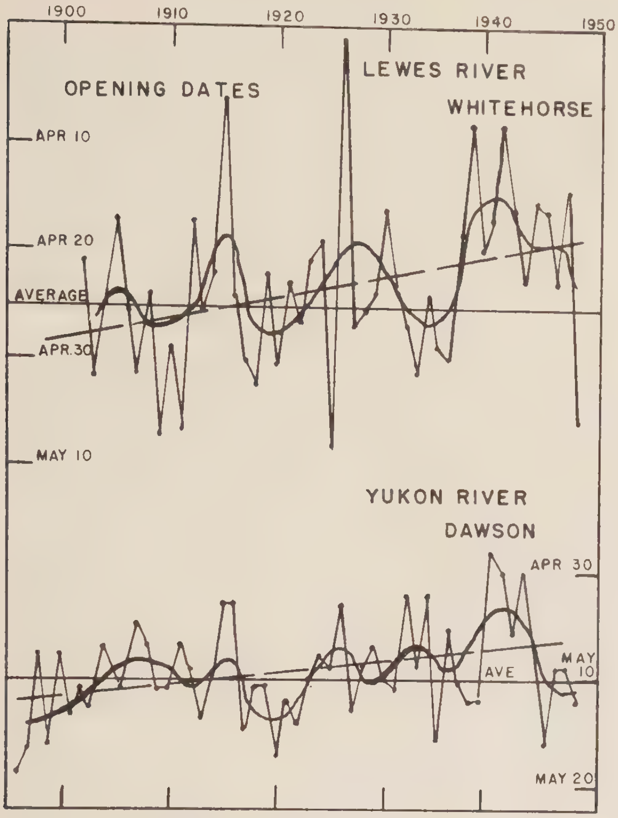


FIGURE 1. OPENING DATES OF THE YUKON RIVER AT WHITEHORSE (LEWES RIVER) AND DAWSON. THE DASHED LINES INDICATE TREND FOR EARLIER OPENINGS IN LATER YEARS.

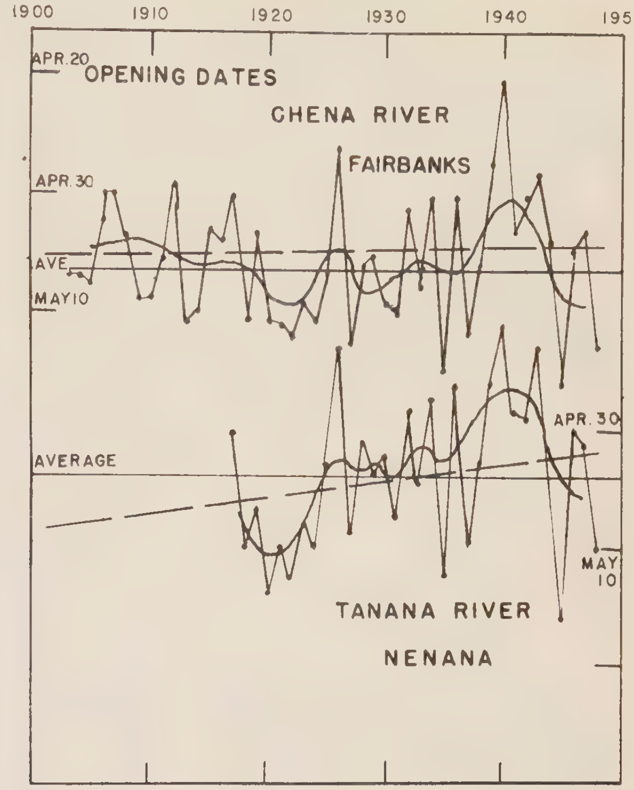


FIGURE 2. OPENING DATES OF CHENA AND TANANA RIVERS IN ALASKA. THE DASHED LINES INDICATE TREND FOR EARLIER OPENINGS IN RECENT YEARS.

Farther southeastward and interiorward is the Peace River, and at the town of Peace River, Alberta, the **Record-Gazette** has reported the records of the opening of peace River there from 1898 to 1948. Through the Editor's generosity, I obtained these data, (Table 4) which were recorded for the most part by the Royal Canadian Mounted Police. These data show some interesting variations (Table 2). The average opening date was April 20, the earliest March 26, 1910 and the latest May 5, 1909, a variation of thirty-nine days. All of this variation occurred in two years, and such a change has not even been approached since. A five-year record of the Smoky River near Grand Prairie parallels the Peace River record.

Major peaks appear to have been reached about 1910, 1916, 1925, and 1939 for an average of 9.7 years (Figure 3). Minor peaks totaled sixteen for an average of 2.9 years.

FALL OPENING

The only record that I obtained of the fall freezing of rivers was that for Lewes River at Whitehorse (1902-1947). The average closing for the record (Table 1) was November 26. The river's earliest closing took place November 1, 1908 and the latest January 2 in the winter of 1943-44, a variation of fifty-two days.

There appear five major peaks about 1907, 1918, 1925, 1936 and 1944 for an average of 9.25 years (Figure 4). There were thirteen minor peaks that averaged 3.1 years apart.

ADDITIONAL RIVER DATA

E. A. Preble (**North American Fauna** No. 27) gave some data for several rivers in the interior (Table 5) that are suggestive of earlier cyclic variations that may have been major peaks about 1881-83 and about 1890-91. The data are fragmentary, but do suggest that in the journals and records of fur traders of the Hudson's Bay Company (from which source came these data) and others will be found further records and that when assembled, they will prove valuable.

The data average later than at Whitehorse or Dawson, which may largely be due to the difference in years, for there appear to have been later openings in the middle of the 19th century, perhaps owing to a long cycle.

The opening of the river at Fort Simpson averages ten days earlier than at Fort Norman during the eight years of joint record. The fall record at Fort Norman shows about twelve days earlier freeze up than at Fort Simpson, 300 miles upstream. It is perhaps two weeks earlier than at Whitehorse on Lewes River.

LENGTH OF FALL AND WINTER

Often have people written about long winters, short winters, as well as mild and hard ones,

FIGURE 3. OPENING DATES OF PEACE RIVER AT PEACE RIVER, ALBERTA, AND NEARBY SMOKY RIVER.

and their influence. The length of summer or winter, using summer and winter in its broadest sense, probably is indicated by the differences between spring opening and fall closing dates. As stated earlier, these seem the best phenological indicators that we have for this region and certainly better than impressions subject to the frailities of the human mind. The days open or closed is fixed and definite; whether the relative number of days indicates the relative length of winter, I cannot say. Whether a long winter as measured this way is also a " hard " one may be debated.

The data at Whitehorse give an average open period of 217 days and closed one of 150 days. Presumably, therefore, we can indicate the summer as of the order of 217 and winter as of 150. The Fort Norman data seem to indicate an open period of 185 and closed one of 180. The data at Fort Simpson indicate open and closed periods of 201 and 164 days.

The maximum open period was 254 in 1943 and the shortest 188 in 1909, a variation of eighty-four days. The longest closed period was 188 days in the winter of 1908-9 and the shortest 104 in

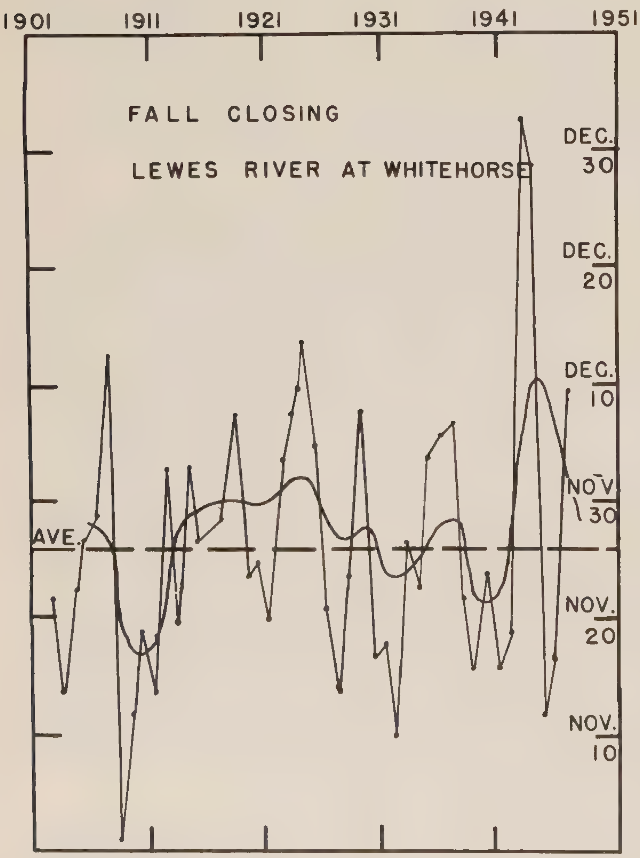


FIGURE 4. FALL FREEZE OF LEWES RIVER (UPPER YUKON) AT WHITEHORSE, YUKON TERRITORY.

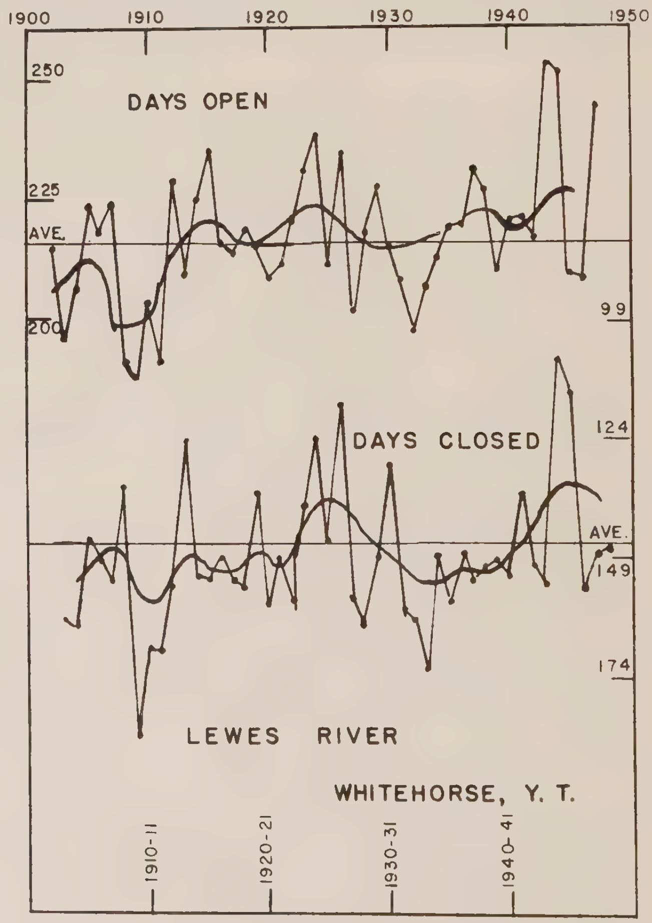


FIGURE 5. THE LENGTH OF SUMMER AS SHOWN BY DAYS OF OPEN WATER IN THE RIVER AND LENGTH OF WINTER AS SHOWN BY DAYS RIVER WAS CLOSED BY ICE.

the winter of 1943-4. Four major peaks appear between 1905 and 1938 that average 9.3 years apart (Figure 5). The peaks of the closed record are not altogether clear, but there appear to have been about five between the winter of 1908-9 and that of 1944-5 for an average of 9.25 years. There were thirteen short fluctuations from 1905 to 1944 that averaged three years in the open-days record and fifteen from 1905-6 to 1945-6 in the closed-days record that also averaged three years.

TRENDS

The data show a rather marked trend in most of the rivers. Because the record is so short, I hesitate to call it other than a trend, though I rather think that at least one longer-cycle is involved and perhaps several.

The trend in Lewes River at Whitehorse and the Yukon at Dawson has been for progressively earlier opening since the beginning of the record. I have drawn on the graphs a dash line to indicate the trend as a straight line. The rate of increase, when converted to a 100-year basis, indicates a progressively earlier opening at Whitehorse at the rate of twenty days a century and twelve days at Dawson.

Roughly speaking, this trend is equivalent to a Northward climatic march of a hundred to a hundred and fifty miles during the period of record at Whitehorse and about eighty-four miles at Dawson.

TABLE 1.

RIVER OPENING AND CLOSING DATES
LEWES RIVER (UPPER YUKON) AT WHITEHORSE, YUKON TERRITORY

YEAR	OPENING DATE	CLOSING DATE	NUMBER OF DAYS OPEN	WINTER	NUMBER OF DAYS CLOSED
1902	APRIL 21	NOV. 22	215	------	---
1903	MAY 2	NOV. 14	196	1902-3	161
1904	APRIL 25	NOV. 23	212	1903-4	163
1905	APRIL 17	NOV. 27	224	1904-5	145
1906	APRIL 25	NOV. 29	218	1905-6	149
1907	MAY 2	DEC. 13	225	1906-7	154
1908	APRIL 24	NOV. 1	191	1907-8	133
1909	MAY 8	NOV. 12	188	1908-9	188
1910	APRIL 29	NOV. 19	204	1910-1	168
1911	MAY 7	NOV. 14	191	1911-2	169
1912	APRIL 17	DEC. 3	230	1912-3	155
1913	APRIL 26	NOV. 20	209	1913-4	144
1914	APRIL 22	DEC. 3	225	1914-5	124
1915	APRIL 6	NOV. 27	235	1914-5	154
1916	APRIL 24	NOV. 27	217	1915-6	149
1917	APRIL 30	NOV. 29	213	1916-7	154
1918	MAY 3	DEC. 8	219	1917-8	155
1919	APRIL 22	NOV. 24	216	1918-9	135
1920	MAY 1	NOV. 25	208	1919-20	159
1921	APRIL 23	NOV. 20	211	1920-1	149
1922	APRIL 27	DEC. 4	221	1921-2	158
1923	APRIL 21	DEC. 8	231	1922-3	138
1924	APRIL 19	DEC. 14	239	1923-4	123
1925	MAY 9	DEC. 5	210	1924-5	146
1926	MARCH 31	NOV. 21	235	1925-6	116
1927	APRIL 27	NOV. 14	201	1926-7	157
1928	APRIL 26	NOV. 24	212	1927-8	164
1929	APRIL 24	DEC. 8	228	1928-9	151
1930	APRIL 16	NOV. 17	215	1929-30	129
1931	APRIL 24	NOV. 18	208	1930-1	158
1932	APRIL 27	NOV. 10	197	1931-2	161
1933	MAY 2	NOV. 27	207	1932-3	173
1934	APRIL 24	NOV. 23	213	1933-4	148
1935	APRIL 29	DEC. 4	219	1934-5	158
1936	APRIL 30	DEC. 6	220	1935-6	147
1937	APRIL 19	DEC. 7	232	1936-7	154
1938	APRIL 8	NOV. 22	228	1937-8	152
1939	APRIL 20	NOV. 16	210	1938-9	149
1940	APRIL 17	NOV. 24	221	1939-40	153
1941	APRIL 8	NOV. 16	222	1940-1	135
1942	APRIL 16	NOV. 19	217	1941-2	151
1943	APRIL 23	JAN. 2	254	1942-3	155
1944	APRIL 15	DEC. 23	252	1943-4	104
1945	APRIL 16	NOV. 12	210	1944-5	114
1946	APRIL 23	NOV. 17	208	1945-6	162
1947	APRIL 14	DEC. 10	240	1946-7	148
1948	MAY 6	-------	---	1947-8	148
AVE.	APRIL 23	NOV. 26	217.3	------	146.9

TABLE 2.

River Breakup, Yukon River at Dawson, Y. T.

Year	Date Opened	Year	Date Opened
1896	May 19	1923	May 10
1897	May 17	1924	May 8
1898	May 8	1925	May 9
1899	May 17	1926	May 3
1900	May 8	1927	May 13
1901	May 14	1928	May 9
1902	May 11	1929	May 7
1903	May 13	1930	May 10
1904	May 7	1931	May 11
1905	May 10	1932	May 2
1906	May 11	1933	May 9
1907	May 5	1934	May 2
1908	May 7	1935	May 16
1909	May 11	1936	May 5
1910	May 11	1937	May 10
1911	May 7	1938	May 12
1912	May 9	1939	May 12
1913	May 14	1940	April 28
1914	May 10	1941	April 30
1915	May 3	1942	May 6
1916	May 3	1943	May 2
1917	May 15	1944	May 5
1918	May 11	1945	May 16
1919	May 11	1946	May 9
1920	May 18	1947	May 9
1921	May 12	1948	May 12
1922	May 14	Average	May 10

TABLE 3.

Opening of Chena River at Fairbanks and Tanana River at Nanana

Year	Chena, date opened	Tanana, date opened
1903	May 7	
1904	May 7	
1905	May 8	
1906	April 30	
1907	April 30	
1908	May 3	
1909	May 9	
1910	May 9	
1911	May 6	
1912	April 29	
1913	May 11	
1914	May 10	
1915	May 3	
1916	May 4	
1917	April 30	April 30
1918	May 11	May 10
1919	May 3	May 7
1920	May 11	May 14
1921	May 11	May 10
1922	May 12	May 13
1923	May 9	May 8
1924	May 11	May 10
1925	May 7	May 3
1926	April 26	April 23
1927	May 13	May 9
1928	May 6	May 1
1929	May 5	May 4
1930	May 8	May 2
1931	May 10	May 8
1932	May 1	April 28
1933	May 8	May 5
1934	April 30	April 27
1935	May 15	May 14
1936	April 30	April 27
1937	May 12	May 11
1938	May 6	May 3
1939	April 29	April 27
1940	April 20	April 21
1941	May 3	April 28
1942	April 30	April 29
1943	April 28	April 23
1944	May 4	April 30
1945	May 16	May 16
1946	May 5	April 30
1947	May 3	May 1
1948	May 13	May 10
Ave.	May 6	May 4

TABLE 4.

Opening Dates of Peace River at Peace River, Alberta and Smoky River near Grand Prairie, Alberta

Year	Peace River Date Opened	Smoky River Date Opened
1898	April 19	
1899	April 26	
1900	April 13	
1901	April 13	
1902	April 24	
1903	April 27	
1904	April 13	
1905	April 17	
1906	April 6	
1907	April 24	
1908	April 24	
1909	May 5	
1910	March 26	
1911	April 22	
1912	April 17	
1913	April 20	
1914	April 20	
1915	April 18	
1916	April 15	
1917	April 23	
1918	April 22	
1919	April 24	
1920	May 3	
1921	April 15	
1922	April 26	
1923	April 25	
1924	May 1	
1925	April 13	
1926	April 15	
1927	April 25	
1928	April 24	
1929	April 24	
1930	April 25	
1931	April 23	
1932	April 25	
1933	April 28	
1934	April 14	
1935	April 22	
1936	April 14	
1937	April 14	
1938	April 14	
1939	April 14	
1940	April 15	
1941	April 11	
1942	April 21	
1943	April 13	April 10
1944	April 16	April 11
1945	April 29	April 20
1946	April 22	April 12
1947	April 16	April 13
1948	May 1	April 30
Average	April 20	April 16

TABLE 5.

River Data for Northern Rivers.

(data from Preble, N. A. F. 27)

Year	Date Opened	Date Closed
	Athabasca River at Fort McMurray	
1878	April 18	------
1879	--------	Nov. 1
1880	May 2	------
1881	April 21	Nov. 12
1882	April 24	Nov. 8
1883	April 25	Nov. 10
1884	April 27	Oct. 28
1885	April 9	Nov. 13
1886	April 16	Nov. 14
1887	April 27	Oct. 24
1888	May 4	Nov. 9
Ave.	April 23	Nov. 6

(Open 197 days, closed 168 days)

Table 5 -- Continued

Year	Date Opened	Date Closed
	Peace River at Fort St. John	
1865	....	Dec. 10
1866	April 19	Dec. 2
1867	April 21	Dec. 3
1868	April 20	Nov. 17
1869	April 23	....
1870	April 26	....
1871	April 18	Nov. 15
1872	April 19	Nov. 28
1873	April 23	Nov. 30
1874	April 19	....
1875	April 16	....
....		
1887	April 26	Dec. 3
1888	May 1	Nov. 16
1889	March 30	Nov. 24
1890	April 30	Dec. 21
1891	April 17	....
Ave.	April 21	Nov. 26

(Open 219 days, closed 146 days)

Year	Date Opened	Date Closed
	Nelson River at Fort Nelson	
1887	....	Oct. 23
1888	May 7	Oct. 31
1889	May 10	Nov. 10
1890	April 30	Nov. 4
1891	April 22	....
Ave.	May 2	Nov. 2

(Open 184 days, closed 181 days)

Year	Date Opened	Date Closed
	Liard River at Fort Liard	
1878		Oct. 29
1879		Nov. 7
1880		Nov. 9
1881		Nov. 13
1882		Nov. 7
1883		Nov. 9
1884		Oct. 31
1885		...... -
1886		Nov. 20
1887		Nov. 9
1888		Nov. 5
1889		Nov. 14
1890		Nov. 14
Ave.		Nov. 9

Table 5 -- Continued

Mackenzie River at Fort Simpson

Year	At Mouth of Liard River Date Opened	Date Closed	Above Mouth of Liard River Date Opened
1876	May 14	Nov. 17	......
1877	May 8	Nov. 28	May 19
1879	May 3	Nov. 20	May 19
1880	May 7	Nov. 26	May 19
1881	May 13	Nov. 18	May 19
1882	May 7	Nov. 30	May 20
1883	May 1	Nov. 20	May 5
1884	May 12	Nov. 18	May 14
1885	May 2	Nov. 20	May 7
1886	May 3	Nov. 25	May 27
....			
1903	....	Nov. 18	......
1904	April 29	....	May 13
1905	May 5	....	May 11
1906	May 3	Nov. 25	May 10
1907	....	Nov. 25	......
Ave.	May 6	Nov. 23	May 15

Mackenzie River at Fort Norman (Open 185 days, closed 180 days)

Year	Date Opened	Date Closed
1872	......	Nov. 8
1873	May 17	Nov. 12
1874	May 25	Nov. 18
1875	May 24	Nov. 9
1876	May 19	Nov. 9
1877	May 12	....
1878	......	Nov. 7
1879	May 9	Nov. 2
1880	May 22	Nov. 12
1881	....	Nov. 2
1882	May 14	Nov. 14
1883	May 11	Nov. 10
1884	May 28	....
1885	......	....
1886	......	Nov. 13
1887	May 24	Nov. 8
1888	May 19	....
....		
1904	May 21	....
Ave.	May 18	Nov. 10

SYNCHRONIZED CYCLIC PROCESSES

Jerome R. Tichy
Colorado School of Mines Research Foundation Inc.
Golden, Colorado.

In the consideration of a multiphase cyclic process it was found necessary, under certain conditions, to make the simplifying assumption that the phase changes of the system might occur in a synchronized way. Before a definition of the cyclic system on the basis of this hypothesis could be made, it was essential first to devise some notation for the process so that it would be possible to determine the affect of phase period variations on the cycle period. In the solution of this problem, a method has been developed which ennables one to handle synchronized cyclic processes in a relatively simple way. Since the application of this method to some special cases, moreover, permits one to gain an insight into the ways in which phase-loss perturbations may arise in cyclic systems, some hypothetical multi-phase systems will be described in this paper based on the premise that the phase changes occur in a synchronized manner.

A two-phase cyclic process is chosen for description such that:

$$N_1\ A \longrightarrow N_2\ B$$

1. N_1 and N_2 are the number of units in phases A and B at the start of the cycle.
2. The units N_1 are in phase. The units N_2 are in phase.
3. The phase changes of A and B are synchronized in the sense that both phase changes start simultaneously.
4. When the sets of units N_1 and N_2 are in the same phase, the units N_1 remain in phase; the units N_2 remain in phase. The sets of units N_1 and N_2 are out of phase by some fractional unit of the phase period in which they are found.
5. The phase periods are integral whole number multiples of each other.

The affect of phase period variations on the cycle period may be seen from the following examples:

1. $t_A = t_B$

$$N_1\ A \longrightarrow N_2\ B$$
$$N_2\ A \longrightarrow N_1\ B$$
$$N_1\ A \longrightarrow N_2\ B$$

2. $t_A = 2t_B$

$$N_1\ A \longrightarrow N_2\ B$$
$$N_1 + N_2\ A \longrightarrow \quad B$$
$$N_2\ A \longrightarrow N_1\ B$$
$$N_1\ A \longrightarrow N_2\ B$$

3. $t_A = 3t_B$

$$N_1\ A \longrightarrow N_2\ B$$
$$N_1 + N_2\ A \longrightarrow \quad B$$
$$N_1 + N_2\ A \longrightarrow \quad B$$
$$N_2\ A \longrightarrow N_1\ B$$
$$N_1\ A \longrightarrow N_2\ B$$

For a three phase system such that

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$

the cycle periods depend on the phase periods as follows:

1. $t_A = t_B = t_C$

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$
$$N_3\ A \longrightarrow N_1\ B \longrightarrow N_2\ C$$
$$N_2\ A \longrightarrow N_3\ B \longrightarrow N_1\ C$$
$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$

2. $t_A = t_C = 2t_B$

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$
$$N_1\ A \longrightarrow \quad B \rightarrow N_3 + N_2\ C$$
$$N_3\ A \longrightarrow N_1\ B \longrightarrow N_2\ C$$
$$N_2 + N_3\ A \longrightarrow \quad B \longrightarrow N_1\ C$$
$$N_2\ A \longrightarrow N_3\ B \longrightarrow N_1\ C$$
$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$

3. $t_A = 2t_C;\ t_C = 2t_B$

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$
$$N_1\ A \longrightarrow \quad B \rightarrow N_3 + N_2\ C$$
$$N_1 + N_3\ A \longrightarrow \quad B \quad N_2\ C$$
$$N_1 + N_3 + N_2\ A \longrightarrow \quad B \longrightarrow C$$
$$N_3 + N_2\ A \longrightarrow N_1\ B \longrightarrow C$$
$$N_3 + N_2\ A \longrightarrow \quad B \longrightarrow N_1\ C$$
$$N_2\ A \longrightarrow N_3\ B \longrightarrow N_1\ C$$
$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C$$

In a four phase system such that

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C \longrightarrow N_4\ D$$

the phase period – cycle period relation is:

1. $t_A = t_B = t_C = t_D$

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C \longrightarrow N_4\ D$$
$$N_4\ A \longrightarrow N_1\ B \longrightarrow N_2\ C \longrightarrow N_3\ D$$
$$N_3\ A \longrightarrow N_4\ B \longrightarrow N_1\ C \longrightarrow N_2\ D$$
$$N_2\ A \longrightarrow N_3\ B \longrightarrow N_4\ C \longrightarrow N_1\ D$$
$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C \longrightarrow N_4\ D$$

2. $t_B = t_C = t_D;\ t_A = 2t_D$

$$N_1\ A \longrightarrow N_2\ B \longrightarrow N_3\ C \longrightarrow N_4\ D$$

$$N_1 + N_4\ A \longrightarrow B \rightarrow N_2\ C \rightarrow N_3\ D$$
$$N_4 + N_3\ A \rightarrow N_1\ B \longrightarrow C \rightarrow N_2\ D$$
$$N_3 + N_2\ A \rightarrow N_4\ B \rightarrow N_1\ C \longrightarrow D$$
$$N_2\ A \rightarrow N_3\ B \rightarrow N_4\ C \rightarrow N_1\ D$$
$$N_1\ A \rightarrow N_2\ B \rightarrow N_3\ C \rightarrow N_4\ D$$

3. $t_A = t_D = 2t_B;\ t_B = t_C$

$$N_1\ A \rightarrow N_2\ B \rightarrow N_3\ C \rightarrow N_4\ D$$
$$N_1\ A \longrightarrow B \rightarrow N_2\ C \rightarrow N_4 + N_3\ D$$
$$N_4\ A \rightarrow N_1\ B \longrightarrow C \rightarrow N_3 + N_2\ D$$
$$N_4 + N_3\ A \longrightarrow B \rightarrow N_1\ C \rightarrow N_2\ D$$
$$N_3 + N_2\ A \rightarrow N_4\ B \longrightarrow C \rightarrow N_1\ D$$
$$N_2\ A \rightarrow N_3\ B \rightarrow N_4\ C \rightarrow N_1\ D$$
$$N_1\ A \rightarrow N_2\ B \rightarrow N_3\ C \rightarrow N_4\ D$$

4. $t_A = 2t_D;\ t_B = t_C;\ t_D = 2t_B$

$$N_1\ A \rightarrow N_2\ B \rightarrow N_3\ C \rightarrow N_4\ D$$
$$N_1\ A \longrightarrow B \rightarrow N_2\ C \rightarrow N_4 + N_3\ D$$
$$N_1 + N_4\ A \longrightarrow B \longrightarrow C \rightarrow N_3 + N_2\ D$$
$$N_1 + N_4 + N_3\ A \longrightarrow B \longrightarrow C \rightarrow N_2\ D$$

$$N_4 + N_3 + N_2\ A \rightarrow N_1\ B \longrightarrow C \longrightarrow D$$
$$N_4 + N_3 + N_2\ A \longrightarrow B \rightarrow N_1\ C \longrightarrow D$$
$$N_3 + N_2\ A \rightarrow N_4\ B \longrightarrow C \rightarrow N_1\ D$$
$$N_2\ A \rightarrow N_3\ B \rightarrow N_4\ C \rightarrow N_1\ D$$
$$N_1\ A \rightarrow N_2\ B \rightarrow N_3\ C \rightarrow N_4\ D$$

From a comparison of the phase period cycle period relation of the two, three, and four phase systems, it is apparent that a general relationship exists between these variables which may be expressed in the form:

$$P_N = \left[\frac{t_A}{t_N} + \frac{t_B}{t_N} + \frac{t_C}{t_N} \cdots\cdots + 1\right] t_N$$

P_N is the cycle period of a system of n phases; t_A, t_B, t_C are the phase periods of the phases A, B, C....; t_N is the smallest phase period of the cycle.

In conclusion it may be said that the method here devised designates the periodic development of certain ideal synchronized cyclic processes. It shows further that these processes, under certain conditions, may evolve with loss of phase perturbations in their periodicities.

NOTES AND NEWS

Resolution 9 of the Fourteenth Conference of Provincial and Dominion wildlife officials placed upon the Canadian Wildlife Service the responsibility for collecting available information about results obtained by investigators of cycles in Canadian wildlife so that it might be more readilly consulted.

The Canadian Wildlife Service would like to have any information of this sort from investigators as well as the names of investigators interested in Canadian wildlife cycles. Communications on the subject should be addressed to

Dr. Harrison F. Lewis, Chief
Canadian Wildlife Service
Department of Resources and Development
Ottawa, Ontario

JOURNAL OF CYCLE RESEARCH

SUGGESTIONS TO AUTHORS

You are writing primarily for people outside of your own discipline. Only one reader in ten will know anything about your field of interest.

Your readers in our Journal will be interested in your paper only because of the **cycles** you refer to or because of the techniques you use in cycle analysis. They will want to compare the findings in your work with their findings in **their** field of interest, or will want you to use a knowledge of cycles in various fields to provide a clue as to possible interrelationships.

Your readers will wish to know as accurately as possible the **length** of the cycle you have discovered or upon which you are reporting. They will wish to know whether this length is changing or is constant. They will wish to know how closely the actual behavior conforms to ideal behavior.

They will wish to know the shape of the waves. Is the average wave sawtooth or sine shaped? Is the average wave symmetrical? What is the amplitude of the average wave? Is it constant?

They will wish to know **timing.** When do the waves in regard to which you are reporting have their crests and troughs, on the average?

They will wish to know if the wave upon which you are reporting is **rhythmic**, or if it is merely a mathematical average in a group of figures?

They will wish to know over how long a period of time the wave has operated--how many repetitions.

They will wish to know the **methods** you used to isolate this wave and to determine its shape, amplitude, period, and timing. They will want to know your methods so that they will know how much faith to put in your results.

Your readers will want to see **charts** showing the raw data and showing the rhythms that you derive as a result of your manipulation of the figures.

They will want your original **raw data** or at the very least, specific references to published sources which are readily available.

Your readers should be equipped by your paper to take your raw figures and follow through your manipulations to come up with the same answers that you achieved, if they should wish to take the trouble to do so. They should have before them all pertinent facts so that they can take exception to your source material or to your manipulations, or to your conclusions.

Your readers would welcome **projections** to show what will happen if the rhythms continue.

Your readers would be glad to have your criticism of the work of others.